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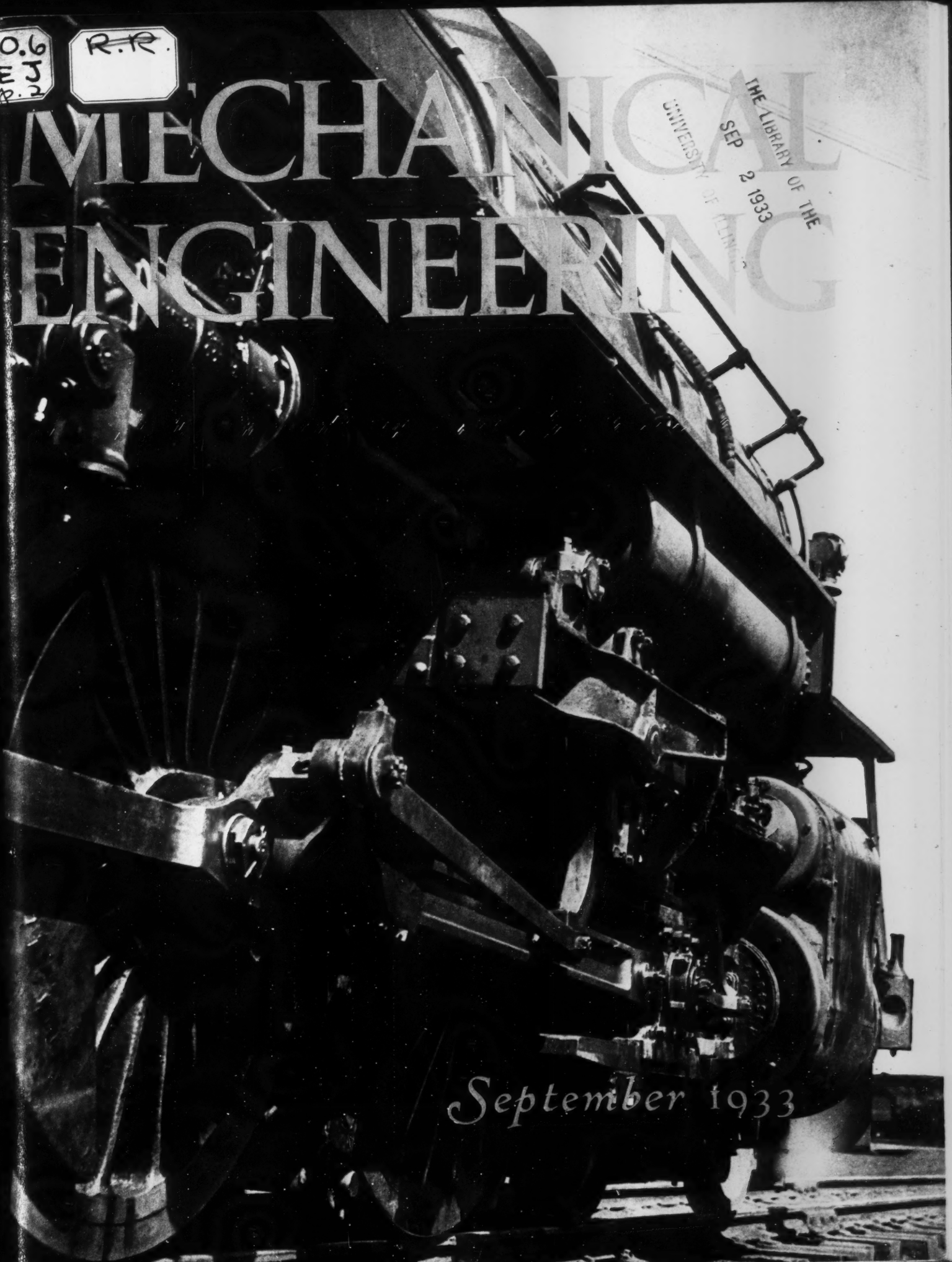

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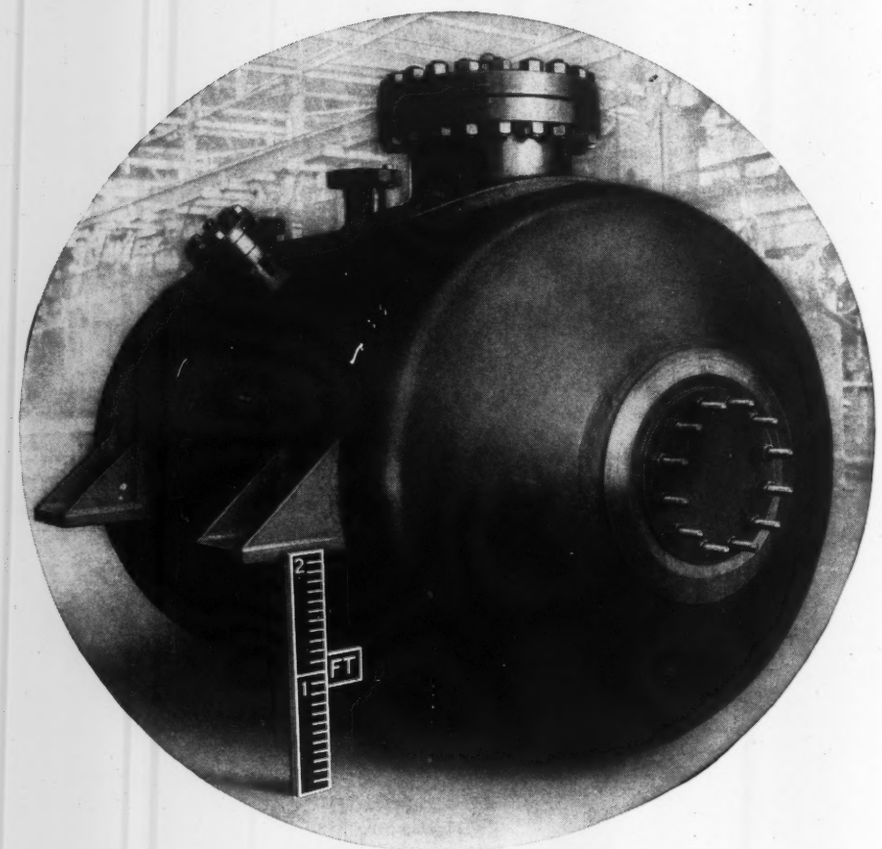

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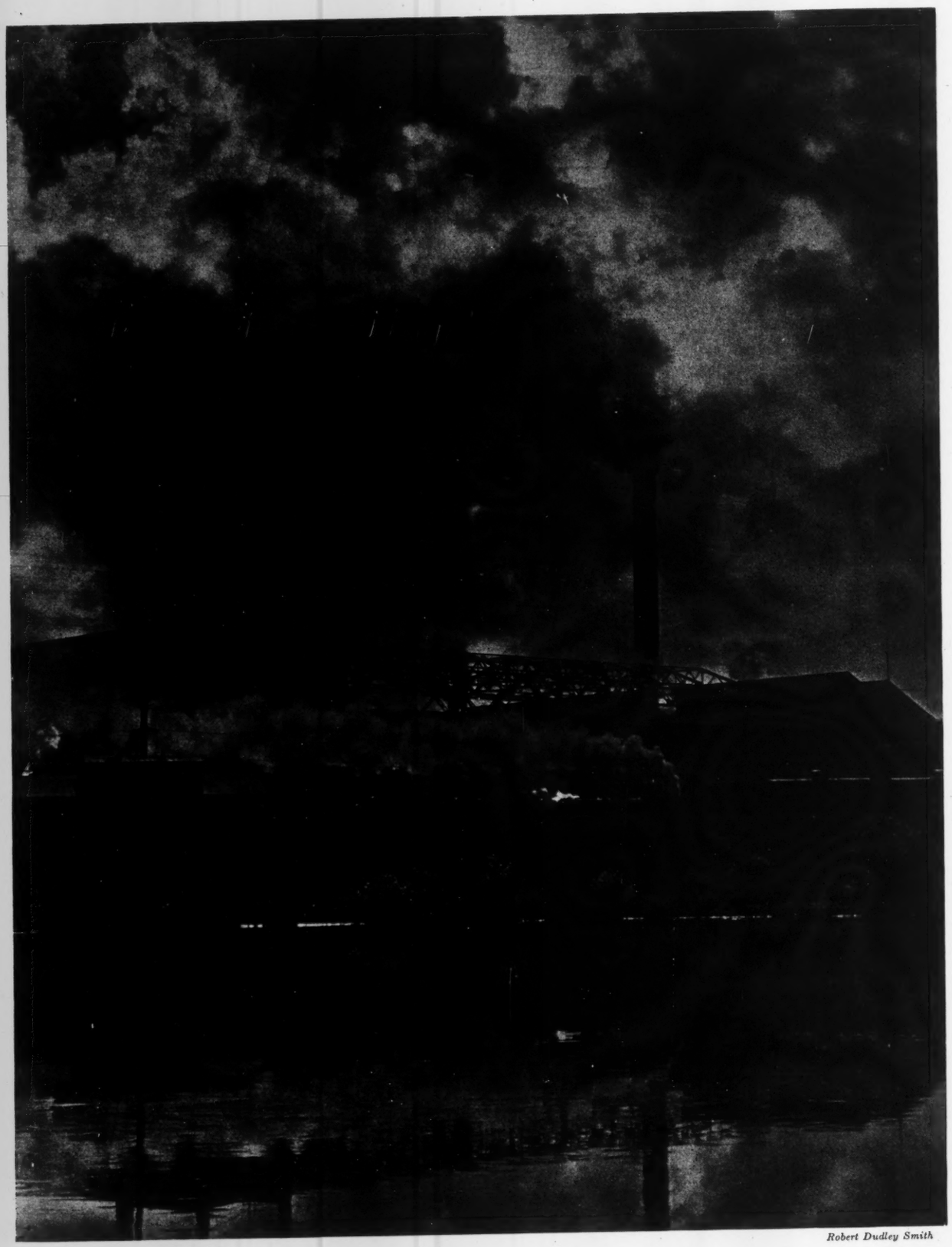

Robert Dudley Smith

Dissolving Clouds

The COMMUNICATION REVOLUTION *1760-1933*

By ROBERT GREENHALGH ALBION[1]

THE PINNING of labels upon certain great movements has helped the student of history to visualize them. About a century ago, the phrase "Industrial Revolution" was applied to the far-reaching consequences of the application of artificial power to the manufacture of goods. Since then, the "Commercial Revolution" and "Agricultural Revolution" have been christened, while the latest edition of a prominent textbook brings us also the "Intellectual Revolution." One more great movement seems to deserve this revolutionary status. This was the remarkable acceleration of transport, travel, and communication which started about 1760 with England's development of canals and turnpikes and still continues with radio and television. For want of a more euphonious title it might be called the "Communication Revolution," using that term in its broadest sense.

Goods, men, and messages did not move as fast in 1760 as they had in Roman times. The rate of communication was determined by the fairly constant potential speed of the horse, modified by the very variable condition of the roads; and the roads of the eighteenth century were poorer than they had been in the days of Augustus and Trajan. Every decade since 1760 has seen a greater development of communication than took place in the whole 1500 years before that date.

In the England of 1760, a speed of 150 miles a day was considered exceptional for couriers with important messages. The normal rate of travel on the main roads was about 40 miles a day, while freight moved at about half that speed. At sea, 75 miles a day was a fair average. In France, the rates would be somewhat faster, while in America, they would be still slower.

The condition of the roads was responsible for those relatively slow rates of land communication. Travelers of the eighteenth century have left most uncomplimentary accounts of the muddy, narrow, rocky, and deeply rutted English roads, even on the main lines of communication. In America, where the roads had recently been hewn out of the wilderness, conditions were even worse. It is small wonder that passengers and freight moved by water whenever practicable. At the same time, however, freshets, droughts, and mudbanks often made river traffic unreliable, while coasting voyages were too often protracted to unreasonable length by the contrariness of the winds. Such were the conditions under which goods, men, and messages had to be moved two centuries ago.

Nesmith, N. Y.

The maximum speed records attained under such circumstances are not impressive. The Scots might transmit a prearranged message, as the ancients had done, by means of signal fires from mountain top to mountain top. Ordinarily, however, the best speed was made by couriers riding night and day, with frequent changes of horses. The fastest recorded time under such circumstances was made by the Pony Express across the American plains and mountains in 1861, just before telegraph wires were stretched over that route. Lincoln's inaugural address was carried by these riders nearly 2000 miles from Missouri to California at the average rate of 256 miles a day. For an approach to such speed, one must go back to Roman times. Conditions at the start of the Communication Revolution produced no such records as those of much earlier times.

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[1] Associate Professor, Department of History; Director, Summer Session, Princeton University, Princeton, N. J.

Presented at Ninth Annual Meeting, New York, N. Y., April 24, 1933, of The American Members of The Newcomen Society. Abridged.

Harper's Weekly, Eighteen Hundred Eighty-Six
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SPEED RECORDS OF THE EIGHTEENTH CENTURY

When the first shots of the American Revolution were fired at Lexington and Concord, near Boston, on the morning of Wednesday, April 19, 1775, a messenger was despatched immediately to carry the news southward over the main post road with all possible speed. The message reached New York, some 225 miles away, Sunday noon, four days after the fighting. A fuller account was sent down over the same route two days later. We have a detailed record of its transmission, giving the day and generally the hour, at nearly forty places between New Haven, Connecticut, and Georgetown, South Carolina. It left New Haven on Monday, April 24, at 9:30 a.m.; reached New York Tuesday at 2 p.m.; Philadelphia, Wednesday at noon; and Baltimore, Thursday at 10 p.m. The distance between those towns in each case was between 90 and 100 miles. The speed slackened as the message reached the Southern colonies with their poorer roads, cut by broad inlets of the sea. "For God's sake send the man forward without the least delay," read a typical Southern endorsement, yet it took five days to travel some 250 miles across Virginia and six days for a similar distance across North Carolina. This can fairly be taken to represent colonial communication at its fastest—an average of about 55 miles a day for the whole run, reaching a maximum of about 100 miles a day between New York and Philadelphia. Had the winds been favorable all the way, it might have traveled faster by water.

In 1603, England had established a faster record, which perhaps had not been exceeded by 1775. Queen Elizabeth died at Richmond, near London, just before 3 a.m. on Thursday, March 26. Sir Robert Carey, a cousin of the queen, hastened to ingratiate himself with the new Stuart dynasty by bringing the first news. Leaving London on Thursday at 9 a.m., he rode at top speed over the Great North Road to Edinburgh, where James was anxiously awaiting the news. Beating the regular messengers of the Privy Council by 30 hours, Carey galloped into the courtyard of Holyrood late Saturday night, having covered the 400 miles in some 60 hours.

SPEED RECORDS OF ANCIENT TIMES

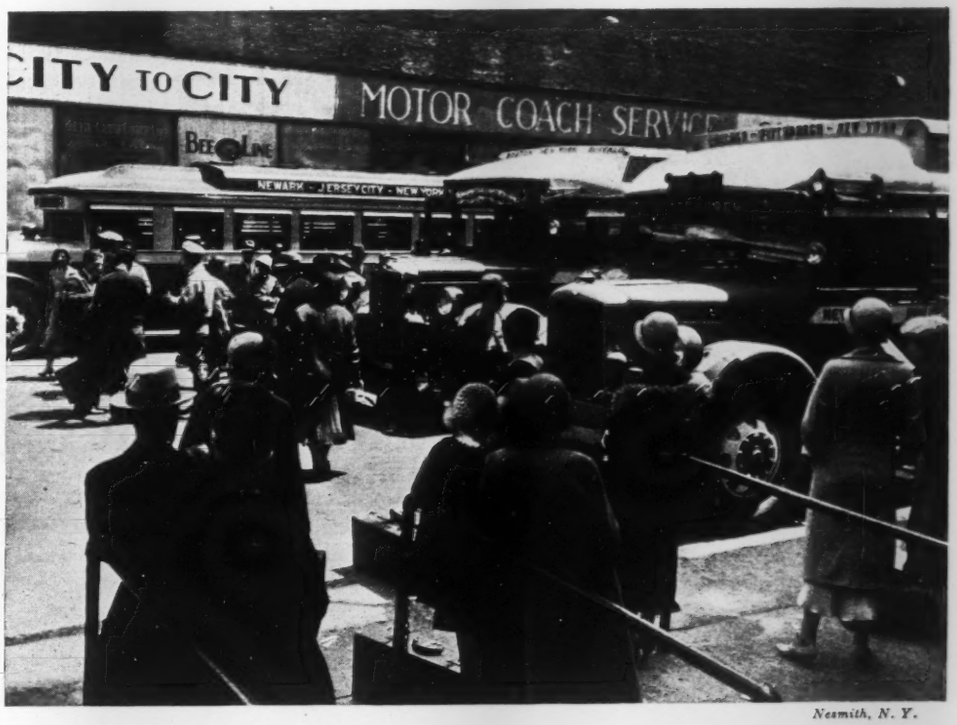
That record seems less impressive when compared with the transmission of an Egyptian letter in 254 B.C. A message of minor administrative importance, it had been sent by the regular official postal system of the Ptolemies 200 miles in 30 hours—a rate of speed identical with Carey's much more urgent haste nearly 2000 years later. The Romans, with their elaborate system of *cursores* speeding over excellent roads, traveled even faster. There is an account of a 600-mile trip from Italy to Germany at the rate of 200 miles a day. The Roman maximum record, it would seem, was a 332-mile trip in 36 hours, equivalent to 220 miles a day, as compared with Carey's 160 miles!

REGULAR EIGHTEENTH-CENTURY TRAVEL

Regular travel, of course, was much slower. The traveler, in the first place, seldom rode at night. The stage coach, springless and uncomfortable, had been in use for about a century in 1760. At that time, it took two weeks to travel the 400 miles between the English and Scottish capitals. Many still traveled on horseback, and, except on the main roads, this was often a necessity. In America, the 225 miles from Boston to New York required at least a week, and it was a marked advance in colonial transportation when two-day service for the 90 miles between New York and Philadelphia was inaugurated in 1770. By sea, six weeks was fair time for a transatlantic voyage, and bad winds often stretched this to ten weeks. In 1759, it took London 33 days to hear the news of Wolfe's victory at Quebec, which was much nearer England than the other American ports.

Freight was generally transported by water wherever possible, but many river towns which had once flourished as seaports had dwindled away when silting blocked

the streams. By land, the packhorse was the common means of transportation over the poorer roads or paths, while four-wheeled wagons, carrying a ton or two, were in use on the main highways. It took one of these wagons three weeks between London and Edinburgh. Small coasting craft consequently did the bulk of the business between ports, particularly in America.



Nesmith, N. Y.

MILESTONES IN THE COMMUNICATION REVOLUTION

Then came the Communication Revolution. Its progress can be marked by a dozen great milestones, each the date when a new development was established on a fairly practical basis. In every case, of course, there was previous important pioneer work by half-forgotten men, while others later were responsible for important improvements. Popular fancy, at least, will probably confirm the following twelve dates: On July 17, 1761, the first barge load of coal was shipped over Brindley's Bridgewater Canal. Late in 1803, Telford went to Scotland to inaugurate scientific road construction on a large scale. On August 17, 1807, Fulton's *Clermont* steamed up the Hudson from New York to Albany. On September 27, 1825, Stephenson's locomotive made a successful run from Darlington to Stockton. On May 2, 1844, Morse sent from Washington to Baltimore the first long-distance telegraph message. On July 27, 1866, transatlantic cable service was permanently established, after an abortive attempt eight years earlier. On March 10, 1876, Bell sent to his assistant the first telephone message. On May 1, 1879, the little electric train of Siemens and Halske at the Berlin Exposition was the forerunner of the developments of Mr. Sprague. On March 4, 1887, Daimler operated the first gasoline propelled automobile. On December 17, 1903, the Wrights made the first successful airplane flight at Kitty Hawk, a few weeks after Langley's plane fell into the Potomac. Finally, on September 30, 1915, the human voice was transmitted from Washington to Hawaii by wireless, paving the way for the rapid development of radio.

Before 1760, the maximum speed of communication seldom if ever exceeded 20 miles an hour. Now, as a result of these inventions, men have traveled 125 miles an hour on the water, 254 miles on land, and 409 miles in the air. Messages can be sent almost instantaneously around the whole earth, while men have traveled that distance in less than eight days. These, of course, are maximum "stunt" speeds, but we are all familiar with the every-day possibilities. From a quantitative standpoint, the figures are also remarkable. The United States alone, for instance, has a quarter of a million miles of railways, 16,000,000 radio receiving sets, 20,000,000 telephones, and 25,000,000 automobiles.

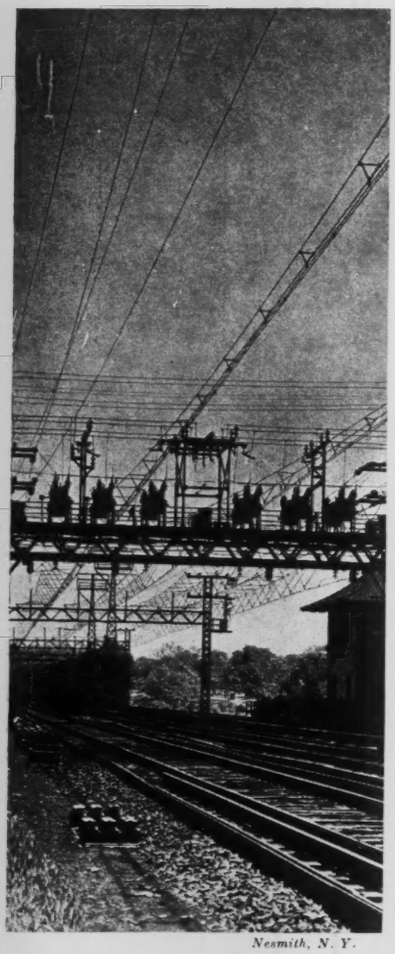
EFFECTS OF COMMUNICATION DEVELOPMENTS ON HUMAN ACTIVITY

The subject is one which permits the juggling of figures to one's heart's content, but the purpose of this paper is not to pile up impressive statistics. It is, rather, to estimate the general effects of the communication developments upon various branches of human activity. Some changes have been simply ones of degree, the new instruments doing the old work more cheaply and quickly. More important are the new features which could not have been possible at all under the old system. These have had a profound influence upon the world and most of its inhabitants.

Starting with the economic consequences of the movement, we find important innovations in the carrying of freight. The packhorse and wagon had served after a fashion for the ordinary articles of transport, provided they did not have to be carried too far. The new methods were necessary for the practicable hauling of two new types of freight—the very bulky and the very perishable, as well as for the economical carrying of freight for long distances overland.

BULKY AND PERISHABLE FREIGHT

Foremost among the very bulky types of freight was coal. The increase in the use of coal, in fact, gave a great stimulus to transportation improvement. The



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British canal boom arose from the desire of the Duke of Bridgewater to market coal from his mines more cheaply in Manchester ten miles away. It formerly took seven packhorses to haul one ton. The new canal gave Manchester a dependable coal supply at about half the old cost. Stephenson's first locomotives, too, were built primarily for the hauling of coal. Today, that still remains an important function of most railroads, some being devoted to it almost entirely.

The other new type of freight is quite the opposite of coal. Our diet has been affected by the facilities for carrying perishable materials. With the invention of the refrigerator car by Swift in 1875, beef, mutton, and pork no longer had to be driven on the hoof to the local slaughter-house. Much of the roast beef of England today has been packed in the American Midwest or in the Argentine, while the mutton comes from Australia or New Zealand. No longer does a community have to depend upon the seasonal supply from local gardens or on costly hothouse products for its fruits and green vegetables. Even milk, which spoils so quickly, is brought daily to great cities from a radius of more than a hundred miles.

CHEAPNESS OF LONG HAULS

The railroad has also made it possible to carry freight for long distances without eating up all the profits in the hauling. It was, perhaps, natural that England should subordinate the communication developments to the Industrial Revolution. The former was essentially a space-destroying movement, and in England there was not so much space to destroy. In America, on the other hand, canals, turnpikes, steamboats, and railroads were doing wonders in linking together our scattered communities at a time when our industries were still legitimate "infants." As soon as our frontier reached the rich potential wheatfields beyond the Alleghenies, success awaited the first seaport to open a cheaper means of transportation from the West.

In the case of sea-borne freight, the changes were not so noticeable. The tramp steamer today performs essentially the same functions as the sailing ship of 1760. The chief value of the steamboat was in releasing shipping from dependence on the whims of the winds. The effects of this new regularity and dependability were more noticeable in short coasting trips and in the harbor functions of ferries and tugs than in the longer ocean voyages. The unique value of the steamer was most apparent in its ability to travel up swift rivers where two-way traffic had formerly been almost out of the question. When Shreve in 1816 built a river steamer that would travel "*on* the water rather than *in* it," he made possible a tremendous interchange of commodities on America's Western rivers during the next half century.

EFFECT ON BUSINESS TRANSACTIONS

The influence on business was not limited to these new facilities for carrying freight. Rapid communication has eliminated much of the former element of chance in business transactions. Financial giants like the Rothschilds maintained an elaborate service of correspondents and couriers. This enabled Nathan Rothschild in London to receive news of Wellington's victory at Waterloo 36 hours after the event, a full day before the official despatches reached the ministers. One cannot blame Nathan for profiting heavily by anticipating the effect of the news upon government securities. Yet Rothschild himself lacked the full and fresh information that is to be found in any metropolitan daily today. The cable, telephone, and ticker have made almost instantaneous common property of much of the world's business information. Since mystery is stripped from the present, business is driven into gambling upon the future.

The same devices have also affected business by tending

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to equalize world prices. The buyer today can ascertain in a few hours the current prices of a commodity, even in different continents. After taking freight and other charges into account, he will normally buy in the cheapest market. This brings into keen competition commercial centers thousands of miles apart. The world-wide effect of this rapid transmission of information and goods was particularly evident after 1869, when the opening of the Suez Canal and the first American transcontinental railroad followed closely upon the permanent establishment of transatlantic cable service. Up to that time, the annual price of grain at New York, Odessa, Liverpool, and Marseilles had frequently shown wide divergencies, due to local conditions. Within ten years, those prices had settled to a virtually uniform level.

EFFECTS IN THE FIELD OF FINANCE

In addition to freight shipments and commercial transactions, a third branch of economic activity has felt the effect of the Age of Speed. The financial world has become involved in the rivalry between the various agencies of communication. The success of a new means of transporting goods, men, or messages has more than once meant heavy losses to investors in the obsolescent methods, while fortunes were being made by those who guessed right on the new. The coming of the railroad meant heavy depreciation of canal and turnpike securities, while money invested in river steamboats and wooden sailing vessels went the same way. For nearly a century, the locomotive held full sway on land, moving nearly everything and every one that had to travel more than a few miles. Profits were good and transportation was an absolute necessity, so railroad securities became favorites with conservative as well as speculative investors. Of the 46 billion dollars of funded debt of American corporations in 1929, 12 billions represented railroad bonds. Of late years, the railroads have been fighting a defensive war on several fronts. The highway is securing revenge for its defeat a century ago, with motor trucks cutting into short freight hauls while buses and private automobiles lure away short passenger traffic. Less serious as yet is the threat of the airplane against longer passenger hauls, to say nothing of the competition of pipe lines and subsidized inland waterways against long freight hauls. The combined impact of these rivalries has reduced, and in some cases eliminated, the railroad's margin of profit. The National Transportation Committee has recently reported the results of its investigation of this situation. In substance, the report separates the problem of the railroad company from that of the locomotive. The latter may lose its old monopoly of transportation, but the committee is more optimistic about the railroad companies. It foresees a possible "beneficent transportation revolution" in which the companies will become general purveyors of transportation, with the locomotive, truck, bus, and airplane each being used for the purpose to which it is best adapted.

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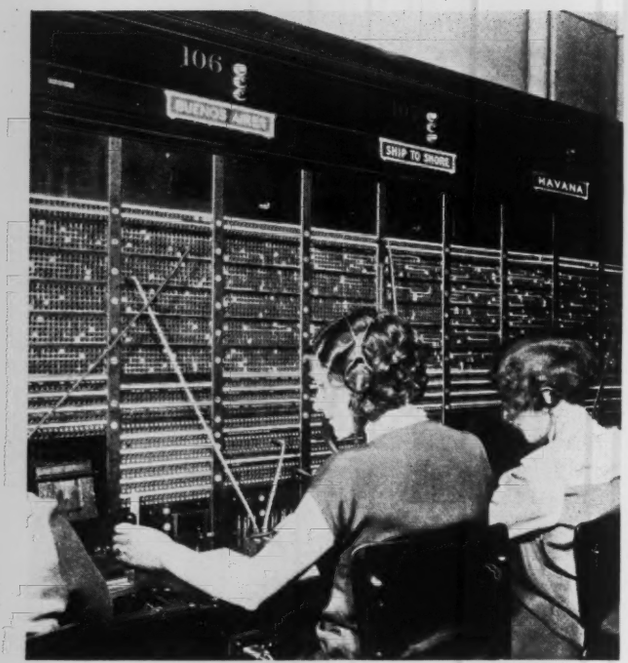
Neesmith, N. Y.

THE SPREAD OF EUROPEAN CIVILIZATION

Leaving the economic field, we find a more dramatic influence of the Communication Revolution in the spreading of European influence over other parts of the world. In exploration, the airplane can accomplish in a few days or hours what formerly took tedious and dangerous months or years in arctic wastes, tropical jungles, and trackless deserts. The mystery is fast being stripped from the last of the world's unknown regions. The permanent control and development of new regions, however, require something more stable than the plane. The railroad and automobile have furnished this. It is an oft-quoted remark that in Europe the railroads followed the population, while in America they preceded it. The railroad played a very important part in spreading civilization over a large part of the North American



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continent. Siberia, Manchuria, and the Sudan have felt the influence of the movement, while the pipe lines from Mosul and the desert motor service to Bagdad can be added to the long list of possible examples.

EFFECTS ON POLITICAL CONTROL

This leads to another very important consequence of the development in communication—the concentration of authority and responsibility, particularly in the field of political control. Colonial administration affords striking examples of this because of the great distances involved. Where an interchange of messages with the home government involved weeks and even months, officials had to be endowed with large powers to meet emergencies. The ministers at home frequently had no control in important crises, and were furnished long afterward with reports of the accomplished facts.

The cable and wireless have completely changed this situation. London is today in closer communication with Ottawa, Cape Town, Sydney, and Delhi than it was with Oxford or Portsmouth in 1760.

The same question of long-distance control has obviously also affected diplomacy. The title of "plenipotentiary" really meant something in the old days. Today, a question raised at Geneva can receive within a few hours replies from ministries at London, Washington, and Tokio.

Even in the home governments, this centralizing effect has been noticeable. The effectiveness of a central government rested, to a certain extent, upon the speed with which it could learn of what was going on in outlying provinces, and with which it could transmit its edicts, following them up if necessary with force. Darius the Persian realized this fact, and Rome later put it into very effective practise. The influence of railways in facilitating the political unity of the United States, Canada, and Germany has often been remarked. Even Louis XIV in the heyday of absolutism could not check up the outlying regions as effectively as can the ministers of democratic France today. The latest national election in Germany has shown how official control of the various instruments of communication can operate to the detriment of the opposition parties.

INFLUENCE ON POLITICAL STRUCTURE

Our political structure in the United States has been influenced by communication. The little counties of our Eastern states, with their costly duplication of effort, are relics of the day of the horse when men wanted to be able to travel to court in a single day. In the Federal Government, the situation is most striking because the distances are greater. Those very distances were argued in 1788 as a reason why representative government was impracticable for so vast an area. Our presidential elections are held early in November, and it was felt at the outset that the results of the election could not be determined to install the new administration until four months later. The present president, and most of the nation as well, knew the results of the people's choice within a few hours after the closing of the polls. His recent inaugural on March 4 is the last that will be held on that date, for our Twentieth Amendment has at last rectified that relic of the stage-coach era. It has also abolished the anomaly of holding a session of a Congress after its successor has been elected. England, in 1931, assembled a new Parliament just a week after a general election, and the same feat would be possible here even with our greater distances.

Not only can democracy assemble its representatives more quickly today, but it can continue more effectively to exert pressure after they are assembled. In the old days, Parliament or Congress could deliberate upon a measure with relatively little outside disturbance. Today, with every stage of a discussion published or broadcast daily throughout the land, the politician can "keep his ear to the ground" and adapt his stand to the attitude of his constituents. This change may be considered an advantage by those who regard the voice of the people as the voice of God.

WARFARE ON LAND INFLUENCED BY RAIL AND MOTOR

Shifting from politics to war, we again notice the radical consequences of accelerated communication. Railroad and motor transport have profoundly influenced land warfare. They have made it possible to concentrate armies rapidly in large numbers, to relieve threatened positions rapidly, to improve the situation of the wounded, and to extend the campaigning distance from a base of supplies. The infantry formerly spent much of their time trudging from one scene of action to another; now they have more time to fight or rest. The fastest corps in Napoleon's dash from the Channel to the Danube in 1805 averaged not quite 15 miles a day, and the usual rate for large bodies was nearer 10. Today, troops can easily be moved at least 700 miles a

day. Wellington remarked that it was not practicable to move more than a hundred miles from a base of supplies, for the men and horses would consume the contents of their own wagons in any longer haul. Today, that distance is greatly lengthened. The situation of the wounded in the old days was bad, both from a humanitarian and a tactical point of view. Now the wounded can be better treated in distant hospitals and can return in better condition for service.

The possibilities of the railroad in war were pointed out by a German as early as 1833. They were used in the Italian campaign of 1859 and gave a full demonstration of their value in the American Civil War. The tremendous and almost immediate concentration of troops on the Western front in the World War was made possible only by intricate railways preparations made by the rival general staffs. The anomaly was that the great mobility in concentration produced prolonged strategical immobility. So many men were quickly crowded into a limited space that there was no room to maneuver. Behind the lines, however, the railroads, supplemented by motor trucks or lorries, did wonders in bringing up supplies and shifting troops to critical points.

TRANSMISSION OF INFORMATION IN MILITARY FIELD

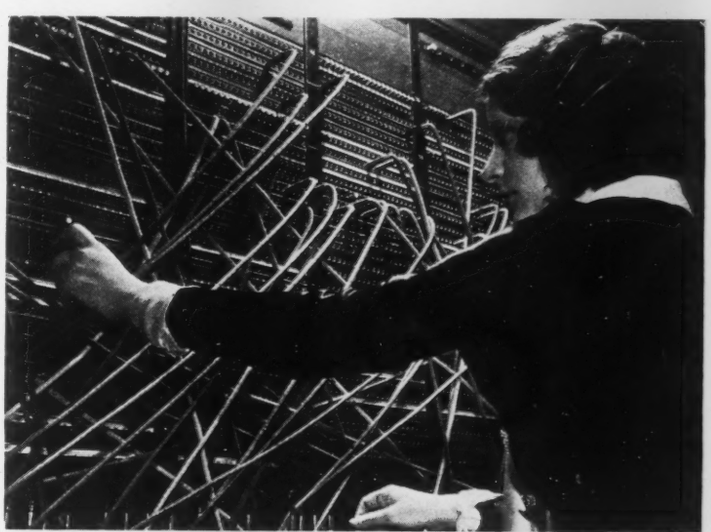
The effect of rapid transmission of information is also evident in the military field. The United States would probably have never fought England in 1812 had there been a transatlantic cable, for England suspended the Orders in Council, the chief American grievance, the day before war was declared at Washington. The only important American military victory in the war was the battle of New Orleans, fought two weeks after the negotiators decided upon peace at Ghent. The new methods of communication have ended such possibilities, and have also done much to concentrate authority and responsibility. The ministry can keep in constant touch with the commander-in-chief, and he, in turn, with his subordinates. The motorcycle and field telephone have displaced the galloping staff rider, while the "eyes of the army" are no longer the cavalry but the air force, which can give wireless information to batteries and make photographic records of enemy lines, to say nothing of bombing positions far in the rear.

Naval warfare has undergone an equally thorough revolution. The application of steam to navigation gave it a regularity impossible to achieve in the days when ship movements were at the mercy of the winds. Those who enjoy playing with the "ifs" of history might speculate upon what would have happened if Napoleon had adopted Fulton's idea of the steamboat in 1804 and towed his flatboats across the Channel on some foggy night when the Royal Navy was becalmed. Wireless, which can even control the movements of a warship from a distance, has added another important element to naval warfare. An analysis of the Jutland operations in contrast to the Trafalgar campaign reveals the tremendous changes in a century.

EFFECT OF COMMUNICATION REVOLUTION ON CITIES

Turning sharply from war, we find another significant consequence of the Communication Revolution in the present great metropolitan areas. H. G. Wells pointed out at the turn of the century that the size of a city has been limited by the desire of its residents to spend not more than an hour in going to work and another hour returning home. As long as most men walked, the city was limited to roughly a four-mile radius from the business center. If it continued to grow in size, it was at the expense of severe overcrowding in housing conditions. Then, with new methods of transportation, a new social type developed in the commuter, who could work in the heart of the city yet have a front lawn and fresh air at home.

New York City is essentially a product of the Communication Revolution. The Industrial Revolution may have been responsible for the growth of Manchester, Birmingham, and Pittsburgh. New York, on the other hand, first drew ahead of its rivals because of its foresightedness in digging a canal to draw grain from the West, establishing liners to draw manufactures from Europe, and utilizing the steamboat to distribute its products along the coast. If new communication devices gave New York its start, they were absolutely necessary to handle its ever-increasing population. In 1800, it had about 72,000 inhabitants; in 1930, the municipal area contained nearly seven million and the whole metropolitan area about eleven million. Ingenuity was taxed in getting the surplus workers to and from their homes. About a century ago, the omnibus and then the horse car were temporary solutions, soon followed by the steam railroad. In 1867, an elevated railroad, using steam at first, was built to relieve congestion on the streets. Twenty years or so later, electricity came to the rescue with surface cars, and later, electric elevated trains. In the meantime, the



Nesmith, N. Y.

Hudson and East Rivers, with their slow ferry service, were barriers to expansion. The Roeblings did important work to relieve this with the Brooklyn Bridge, opened in 1883 and soon followed by other bridges. In 1904, New York opened its first subway, and within ten years several tunnels under the Hudson and East Rivers were opened.

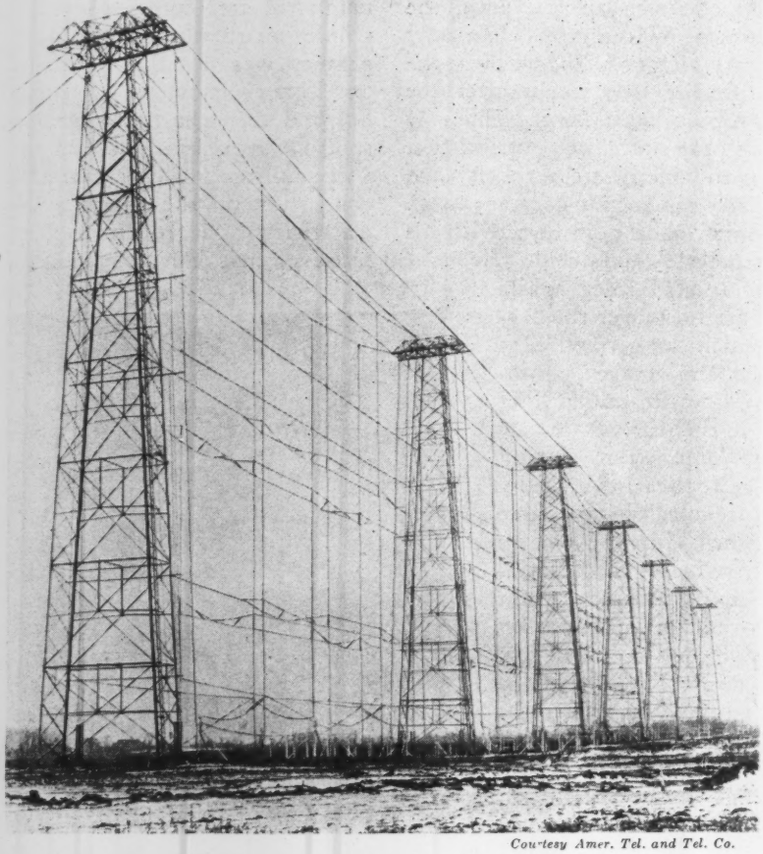
EFFECT OF COMMUNICATION REVOLUTION ON THE INDIVIDUAL

Above all, inventions have tended to broaden the horizon of the average person in a remarkable way. We can appreciate this as we look back at eighteenth-century conditions before the movement started. "The vast body of colonists," writes Dr. Andrews, "stayed at home. They led quiet and uneventful lives, little disturbed by the lust for travel and seldom interrupted by journeys from their place of abode." That description would serve not only for colonial America but also for most of contemporary England and Continental Europe. The average village was practically cut off from the outside world, especially in winter. News of great outside events trickled in slowly, frequently months after they happened. Localism was extreme, residents of the next county were regarded as aliens, and quaint local customs, prejudices, and superstitions flourished in that atmosphere of isolation.

An increase of travel was the first obvious result of the new developments. In the old days, the great majority probably never in the course of their lives went more than 50 miles from their birthplace, and for many 20 miles would be the limit. Fashion, urgent business, emigration, or an incurable wanderlust were the chief motives for such travel as there was. The slowness, expense, and discomforts of travel combined with inertia to keep most of the people at home. The railroad did much to increase travel, but the automobile has done infinitely more. In 1895, only four automobiles were registered in the United States; at present there is one for almost every family. It has become an important influence in the life of the individual and its speed has done much to increase the tempo of modern life. Always available, it gives the owner a new control over his movements, while it creates and gratifies a wanderlust. In 1930, on a per capita basis, the average American traveled some 57 miles by bus, 106 miles by electric lines, 218 miles by steam railroads, and 2697 miles by automobile. That same year, 445,000 American citizens sailed from Atlantic and Pacific ports, about half of them visiting Europe, where they spent more than $100,000,000.

Even for those who do not travel far from home, outside contacts have greatly increased. In the matter of out-of-town first-class mail, the "per capita" American about 1790 received one letter in five years; at present he receives one every four days. Telephones have increased until they are nearly as common as automobiles, and from almost every telephone one can be quickly connected, if he will pay the price, with all but about 2,000,000 of the 35,000,000 phones in the world. It was reckoned in 1927 that the "per capita" American received a local telephone call every day and a half, a telephone toll call every forty days, a telegram every six months, and a cable once in eight years.

To these might be added the effects of certain instruments of so-called "mass communication." The oldest of these, the newspaper, has utilized the other means of communication to present to millions, morning and evening, the latest account of important happenings in all parts of the world. The moving pictures, particularly the news reels, serve as communication of a sort. Finally, the almost miraculous spread of the radio during the past thirteen years has been perhaps the most dramatic achievement in communication. Even to homes far distant from the centers of population, it brings throughout the



Courtesy Amer. Tel. and Tel. Co.

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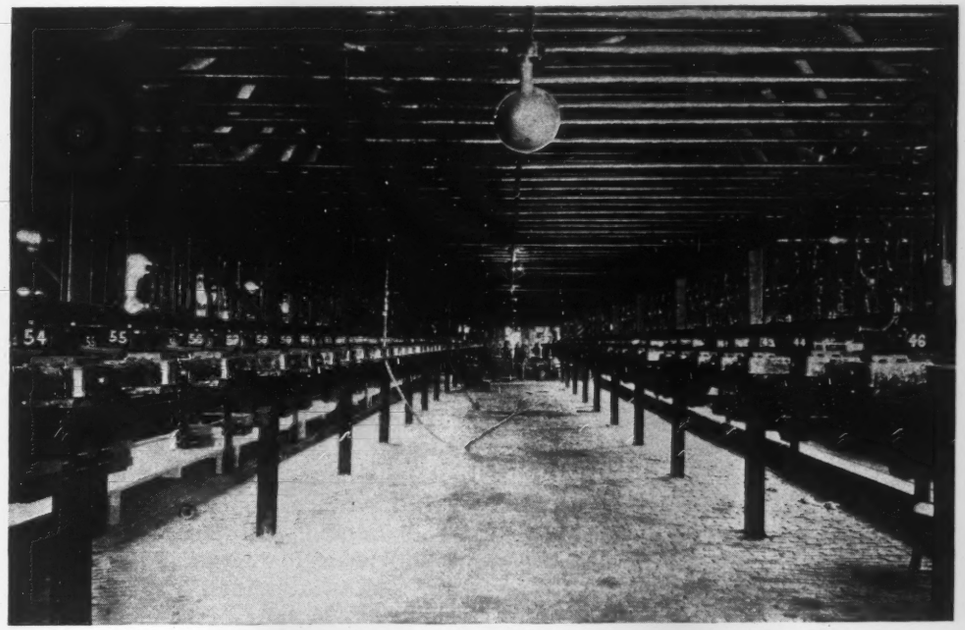


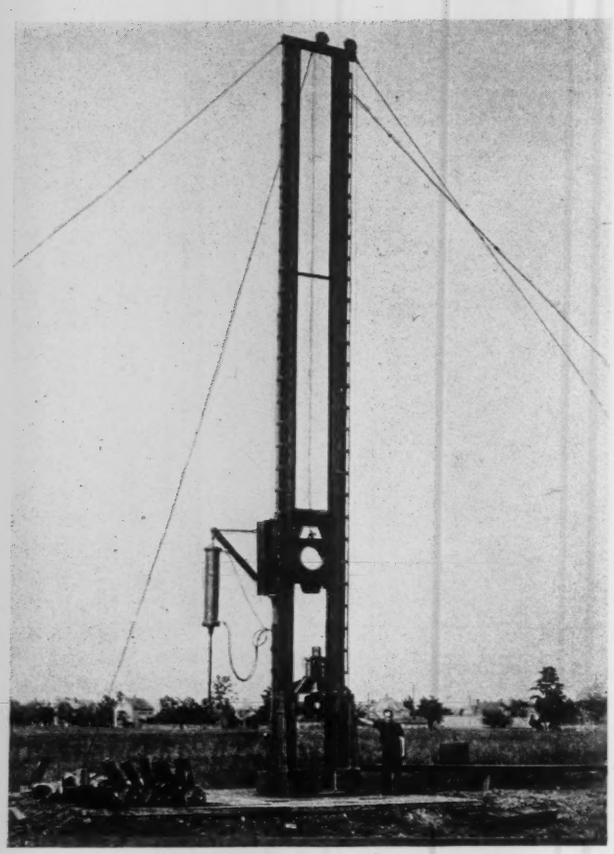
POWER-BRAKE LABORATORY AT PURDUE

RESEARCH *in* RAILWAY ENGINEERING

A Report of Papers and Discussions at the Chicago Meeting of the A.S.M.E. Railroad Division

ONE HUNDRED YEARS is a short space of time in the history of mankind, but the Century of Progress, so dramatically commemorated this year in Chicago, covers practically the entire history of railway development. One hundred years ago this infant transportation agency was more of a potential than an actual threat to the time-honored methods of travel over land, and to the substitute inland water routes that had sprung up to meet the demands of cheaper ways of getting about and moving goods. In railroading, there were romantic, adventurous, and profitable careers awaiting men of vision and determination. There were tremendous physical and technological handicaps to be overcome, and abundant opportunity for the exercise of resourcefulness, inventive ability, and imagination in surmounting obstacles and developing an important industry. Conservatives who jeered soon stilled their voices, or were forgotten. In this country, vast rich and uninhabited regions awaited a colonization that no other agency had ever promoted so rapidly. Settlers on the frontiers clammered for this method of communication with the Atlantic Seaboard and Europe, and rapidly developing industry and commerce in the towns and cities of the East were quick to seize this means of bringing themselves closer to sources of raw materials and markets. To be sure, unrestrained speculation, unscrupulous promoters, and the enthusiasm of overexpansion in railways contributed to some of the economic disturbances that remain as blots on the Century of Progress, but the balance was heavily in favor of railway transportation throughout this period of industrial development and empire building.

With the turn of the century, however, new factors became involved, and the period of railway building entered its mature stages. Other means of transportation seized popular attention. Certain abuses and "the-public-be-damned" spirit chilled popularity. Legislatures discovered in the railroads a profitable source of revenue, and the railroads found themselves unfriended, harassed on all sides, and the object of attack by muckrakers and critics. Any one could criticize and every one did, with the result that, at the end of a Century of Progress, the railroads that had been developed out of mere nothing by man's ingenuity and persistence and that had made



IMPACT DROP-TESTING MACHINE

possible the transformation of a wilderness into a prosperous nation of vast mineral, agricultural, and industrial wealth, were being accused of lack of vision and progress and of having failed to keep pace with more recent developments in the country's industrial and economic life.

Such is the background and such the reason for the recent sessions at Chicago, during Engineering Week at a Century of Progress Exposition, under the auspices of the Railroad Division of The American Society of Mechanical Engineers. In the atmosphere of a professional engineering society and the impressive display of the Exposition, these session produced the evidence to show that the popular criticism of the railroads for lack of research and development is, in general, not founded on fact, but that, on the contrary, the railroads have been availing themselves of contemporary progress and have been greatly benefited by research and technological development.

THE A.S.M.E. PROGRAM

In developing a program to bring out the important and impressive achievements relating to progress in railroad research, the A.S.M.E. Railroad Division, under the leadership of L. K. Sillcox, vice-president, New York Air Brake Company, its chairman, and W. H. Winterrowd, vice-president, Lima Locomotive Works, Inc., chairman of the subcommittee on meetings and papers, followed the convenient and natural divisions represented by (1) research conducted by the railroads, (2) research conducted by the industries serving the railroads, and (3) research conducted by the universities.

Reports of what has been accomplished were presented at the morning session at which L. A. Downs, president, Illinois Central Railroad, presided, following an introduction by Dean A. A. Potter, president, A.S.M.E. The opening address by R. H. Aishton, chairman, American Railway Association, was followed by papers by Col. C. D. Young, vice-president, Pennsylvania Railroad, who reported on the research done by the railroads; by Samuel O. Dunn, chairman of the board, Simmons-Boardman Publishing Co., and editor, *Railway Age*, covering the work of the industries; and by Prof. Gilbert A. Young, of Purdue University, and Professors Edward C. Schmidt and Everett C. Young, of the University of Illinois, who reviewed the research which these universities have conducted.

The afternoon session was presided over by Roy V. Wright, managing editor, *Railway Age*, and past-president, A.S.M.E., and the following discussions were presented.

"A.R.A. Standardization of Freight Equipment," by F. H. Hardin; assistant to president, New York Central Lines, New York, N. Y., member, A.S.M.E.; "Car Trucks and Steel Castings," by Harry M. Pflager, senior vice-president, General Steel Castings Corporation; "Locomotive and Car Wheels," by C. T. Ripley, chief mechanical engineer, Atchison, Topeka, and Santa Fe, Chicago, Ill., member, A.S.M.E.; "Passenger-Car Developments," by Peter Parke, chief engineer, The Pullman Company, Chicago, Ill., member, A.S.M.E., "Automotive Engines and Cars," by L. C. Coleman, manager, Locomotive Department, Ingersoll-Rand Company, New York, N. Y.; "Research in the Railroad Braking Art," by Samuel W. Dudley, professor of mechanical engineering, Yale University, New Haven, Conn., member, A.S.M.E.; "Progress in the Development of Draft Gears," by L. P. Michael, chief mechanical engineer, Chicago and North Western, Chicago, Ill., member, A.S.M.E.; "Research Related to Locomotive Development," by W. E. Woodward, vice-president, Lima Locomotive Works, Inc., New York, N. Y., member, A.S.M.E.; "The Locomotive Boiler," by H. B. Oatley, vice-president, The Superheater Company, New York, N. Y., member, A.S.M.E.; "Locomotive Running Gear and Counterbalancing," by A. G. Trumbull, chief mechanical engineer, Advisory Mechanical Committee, Chesapeake and Ohio, Pere Marquette, Erie, and New York, Chicago, and St. Louis, member A.S.M.E.; "Locomotive Valves and Valve Gears," by G. S. Edmonds, superintendent of motive power, Delaware and Hudson; "Locomotive Accessories," by C. H. Bilty, mechanical engineer, Chicago, Milwaukee, St. Paul, and Pacific, member, A.S.M.E.; "Anti-Friction Bearings in Railway Service," by J. R. Jackson, engineer of tests, Missouri Pacific, St. Louis, Mo., member, A.S.M.E.; "Railroad Equipment of High-Tensile Steel," by Edward G. Budd, president, Budd Manufacturing Company, Philadelphia, Pa.; and "Research and Development in Car and Loco-

motive Materials," by Lawford H. Fry, railway engineer, Edgewater Steel Company, Pittsburgh, Pa., member, A.S.M.E.

IMPORTANCE OF THE MEETING WIDELY RECOGNIZED

That this program was recognized as being of great importance to the railroads is indicated by the fact that the American Railway Association gave it its full support, the chairman of the board of the A.R.A. making the opening address, and devoted the following day, in one of its own meetings, to a further discussion of the same subject.

Space will not permit the printing of the papers and discussions. In this connection, however, mention should be made of the full and enthusiastic cooperation of the *Railway Age*. Not only did the chairman of its board deliver one of the principal addresses, but the issue of July 1 was devoted to research and development, and included, in addition to abstracts of the paper and discussions on the A.S.M.E. program, which were chiefly concerned with the mechanical engineering aspects of subject, articles on many other phases of research in railroading, prepared by its own staff.

WHAT THE RECORD SHOWS

In his brief but comprehensive survey of railroad developments, Mr. Aishton showed that in the past fifty years the transportation demands of the country had increased tenfold. While population had increased by 150 per cent, the average rail-transportation demand per individual had grown fourfold.

Coordinated effort and a cooperative spirit had produced many refinements in rail service, he said. A recent summary had showed that, during the last 15 years, the railroads had attacked more than 3000 problems dealing with operating and mechanical practises and construction standards. Of equal importance with this cooperative work, he continued, was the research conducted by the railroads through their own laboratories and organizations and by manufacturers.

Taking as an example the unit costs of railroad operation, Mr. Aishton showed that if the business of 1929 had been handled on the operating unit costs of 1920, the railway operating expenses in 1929 would have been greater than they were by $1,212,000,000.

Also referring to economies, Mr. Dunn pointed out that in fuel alone, comparing 1929 with 1920, the saving amounted to $91,300,000. On the basis of 1893 methods and plants, 1929 would have required 3,146,800 employees instead of 1,661,000, and the 1929 payroll would have been $6,000,000,000 instead of actually less than $3,000,000,000. In this 40-year period, he said, investment had increased 178 per cent; employment, 90 per cent; traffic units, 300 per cent; units handled per dollar of investment, 42½ per cent; and units handled per employee, 108 per cent.

AGENCIES RESPONSIBLE FOR DEVELOPMENT

As has already been suggested, developments in railroading have been brought about through the cooperative and coordinated efforts of the railroads themselves, the manufacturers that supply them with materials and equipment, and the universities that have made railroad problems a particular subject of research study. Mr. Dunn called attention to the work of the American Railway Association and many manufacturers' associations in contributing to the developments in railroading. Through such agencies as the American Railway Car Institute, the Four-Wheel Truck Manufacturers Association, the Association of Manufacturers of Chilled Car Wheels, the Association of Steel Manufacturers, and many others, problems of mutual interest to the manufacturers and the railroads had been worked out; and as he and Colonel Young and the heads of the University laboratories pointed out, all of these agencies—railroad, association, university, and individual manufacturer—had cooperated most effectively. This evidence presented a clear answer to Mr. Dunn's question: Does it seem probable that a great electrical or steel company, which manufactures for both the automobile and the railroad industries, would show great initiative and resourcefulness in contributing to the progress of the one, and a conspicuous lack of the same qualities in contributing to the progress of the other?

In so far as the work done at the universities was concerned, the papers by Professor Young, of Purdue, and Professors Schmidt and Young, of Illinois, made

DRAFT-GEAR TESTING EQUIPMENT

gracious acknowledgements of the energy and vision of W. F. M. Goss, who initiated the work at Purdue, and to L. P. Breckenridge, through whose efforts the Engineering Experiment Station was established at Illinois. Both papers developed in detail the work carried on under numerous auspices at these institutions. Briefly, this work includes, at Purdue, the first locomotive testing plant, and the systematic testing of railway equipment growing up as a result of it, such as the air brake, the brake shoe, the car coupler and draft gear, and the wheels themselves, and other studies on the superheater and the development of the front end; and, at Illinois, the work with the dynamometer car, the electric test car, the special railway electrical laboratory, the brake-shoe testing machine, the drop-test machine, and the fully equipped locomotive testing plant, with which facilities there have been investigated stresses in railway brake shoes, thermic siphons, stresses in railroad track, train resistance and tonnage rating, locomotive front ends, and many other problems.

THE LOCOMOTIVE

Only brief mention can be made of some of the high spots in the discussions relating to developments in individual pieces of equipment. The locomotive, quite naturally, provided the opportunity for the greatest amount of development of interest to mechanical engineers.

Mr. Dunn, in a general survey, called attention to the improvements in design and materials permitting a working pressure of 300 lb in the conventional fire-tube boiler, with service life extended two or three times. He showed how the superheater had resulted in saving about 22 per cent of the fuel, and how feedwater heaters had saved 12 per cent in fuel and water; how thermic siphons had improved water circulation; how the steel casting had been developed so that the single-piece locomotive bed frame had taken the place of what was formerly made up of 250 parts; how the locomotive booster had increased tractive effort on heavy grades and in starting; and how such devices as the mechanical stoker, the power reverse gear, the mechanical lubricator, and innumerable others had contributed to satisfactory locomotive performance.

Colonel Young told of the increase of tractive power of 60 per cent since 1911, of economies in fuel and in the expenditure of human labor in locomotive operation, of increases in tender capacity to eliminate stops and expedite traffic, of higher speeds with less danger to track structures, and of interchangeability in locomotive parts.

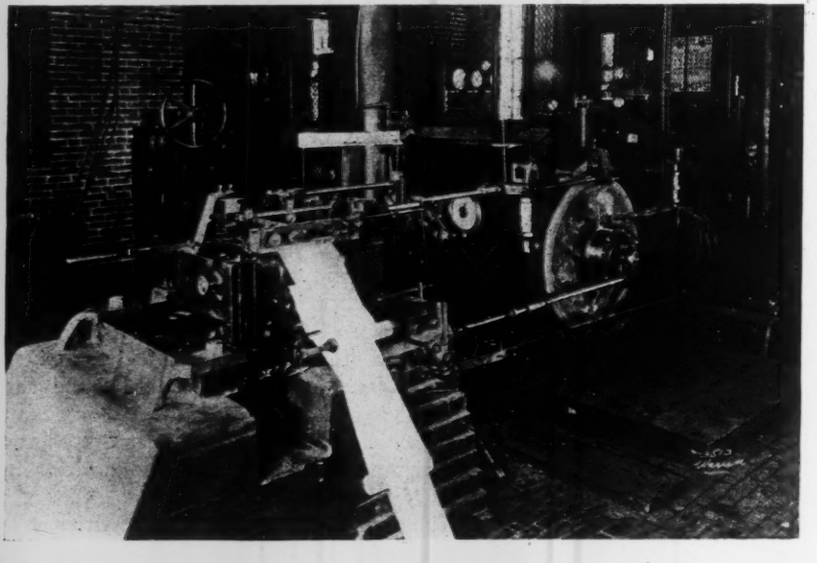
W. E. Woodward reviewed early research on train resistance by Clark, in 1855, Wellington, in 1887, and Goss, in 1889; the Schmidt formulas, and the locomotive tests of the Pennsylvania Railroad; the work of F. J. Cole in establishing locomotive ratios; and as an example of his contention that "locomotive designs do not just grow," he sketched the developments in preparation for the basic design of the 2-8-4 type locomotive, known as A-1, built by Lima in 1925, and the subsequent road trials in which eight railroads cooperated.

A table of changes in boiler characteristics during the past 30 years was presented by H. B. Oatley, showing increases in steam pressure from 180 to 250 lb per sq in.; in superheat from zero to 300 deg; in Btu per pound of steam from 1198 to 1373; in pounds of steam per hour from 23,200 for passenger and 35,000 for freight to 63,500 and 82,000; and in Btu per hour per pound of boiler, water, and superheater from 397 and 493 for passenger and freight, respectively, to 680 and 643. He also mentioned the multi-pressure locomotives that have been in service under test conditions on the Canadian Pacific and the New York Central.

Speaking of locomotive running gear and counterbalancing, A. G. Trumbull reviewed recent practise in increasing counterbalance capacity and noted the development of special steels and roller bearings.

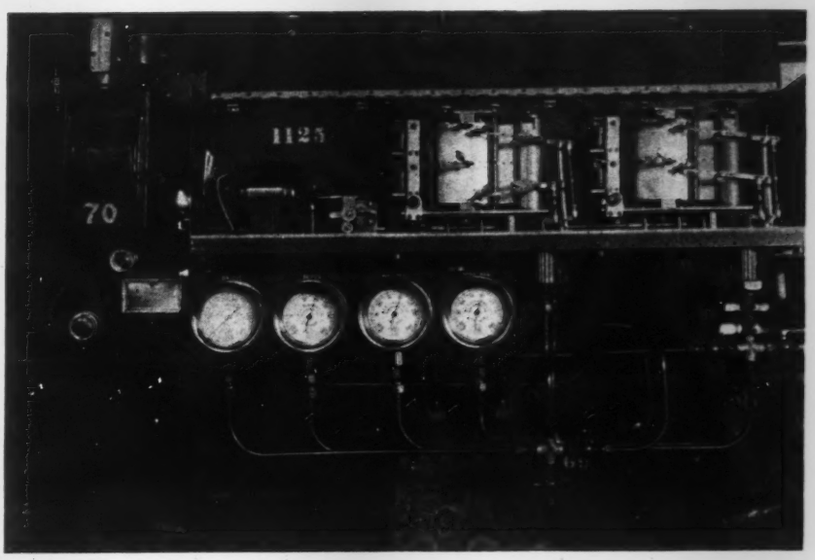
G. S. Edmonds reviewed briefly developments in slide, piston, and poppet valves, with particular reference to the studies of the Delaware and Hudson, and expressed the opinion that, confronted with the economical use of the expansive qualities of steam, and in view of the 5 per cent cut-off operation in Italy, we were approaching the time when more serious consideration would have to be given to the development of the poppet valve.

A number of locomotive accessories that had been developed in locomotive practise, and some that had been adapted from stationary-plant practise, were listed by C. H. Bilty. In answering the question why the rail-



BRAKE-SHOE TESTING MACHINE

roads themselves had not created, experimented with, and developed all the accessories for locomotives, Mr. Bilty reminded his audience that a railroad's object was to sell transportation, and, therefore, it had no interest in the commercial activities relative to the development of the locomotive and its parts. He showed that the success of a new device depended on cooperation between the user and the manufacturer in the various stages of development.



POWER-BRAKE TRAINAGRAPH

ELECTRIC AND INTERNAL-COMBUSTION EQUIPMENT

In addition to developments in steam locomotives, Mr. Dunn spoke of equivalent advances in the design of electric and internal-combustion locomotives resulting from research. Cooperation between manufacturers and railroad companies had developed internal-combustion locomotives that had demonstrated notable economies, particularly in switching service, where high percentage of availability, low fuel consumption, and low labor cost of operation, as well as reduced maintenance expense and freedom from standby loss, had effected savings of $10,000 per year per locomotive. Internal-combustion-driven rail cars, he said, had become highly efficient and reliable units, and he gave the following four-year average figures for one road: availability, 93.3; total operating costs, including interest and depreciation, 36 cents per mile; total saving over equivalent steam-train operation, 21 cents per mile; total return on investment, 123 per cent in four years.

Speaking of automotive engines and cars, L. G. Coleman said that on December 31, 1932, there were in service in the United States and Canada, 127 oil-electric locomotives, 11 gas-electric locomotives, 32 oil-electric rail cars, and 737 gas-electric rail cars. He pointed out the differences in the operating characteristics and duty cycles of steam and internal-combustion engines and the effects these had on locomotive operation. It was possible, he said, to build a 4000-hp Diesel-electric locomotive with 50,000 to 60,000 lb on the drivers, and it was his belief that the next few years would find them entering the field of main-line service in considerable numbers.

CAR EQUIPMENT

Mr. Dunn called attention to many highly important developments in car design that had materially affected the comfort and convenience of passengers, such as heating and air-conditioning equipment and lighting arrangements. The first Pullman sleeping car was built in 1859, the six-wheel truck came in 1876, the vestibule in 1887, the axle-generator and storage battery for electric light in 1899, and all-steel constructure in 1907, while aluminum alloy and light-weight alloy-steel construction had been developments of the last three years. He emphasized the developments relating to safety, especially the air brake and improved braking equipment, on which the American Railway Association had spent $2,250,000 in recent tests. Streamlining for high speeds, decreasing air resistance 35 to 40 per cent, the use of rubber for cushioning and noise prevention, anti-friction bearings, and improved lubrication were also called to the attention of his audience. These improvements and developments were likewise touched upon by Colonel Young and by Peter Parke. The razor-blade slot, that has received so much newspaper comment, was not mentioned.

FREIGHT EQUIPMENT

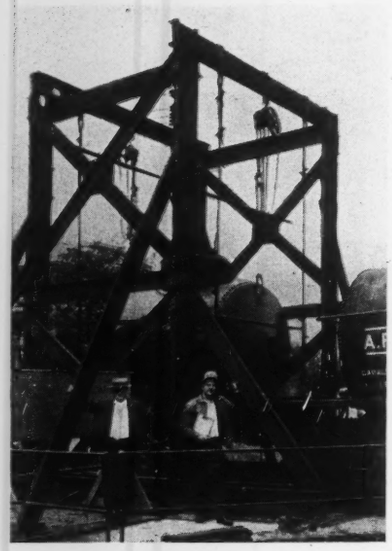
Improvements and developments alluded to by Colonel Young in speaking of research in freight equipment and operation related to air brakes, the so-called non-harmonic spring to protect the contents of cars from damage, draft gears and couplers, portable containers, special freight equipment for miscellaneous commodities and special kinds of merchandise, special cars for automobiles, the standardization of freight cars, and protection against deterioration by corrosion.

F. H. Hardin reviewed what the American Railway Association had done in the standardization of freight equipment, listing the six items of the program formulated after the June, 1931, convention, and the cooperative work undertaken in connection with the American Railway Car Institute. Harry M. Pflager spoke on car trucks and steel castings, and C. T. Ripley on locomotive and car wheels. Research in the railroad braking art was discussed by Samuel W. Dudley, progress in the development of draft gears by L. P. Michael, and anti-friction bearings in railway service by J. R. Jackson.

MATERIALS

That new and improved materials developed by the industries have been adopted for use by the railroads

was evident from the testimony offered by most of the speakers. Particularly, the use of light-weight alloys and rubber were emphasized by Mr. Dunn. Developments in the technique of steel casting have figured largely in improved, stronger, and simplified design. An alloy of iron-chromium-nickel, introduced as stainless steel, has been adopted for structural purposes, as explained by Edward G. Budd. This steel, annealed, has a normal strength of 100,000 lb, and when cold worked by rolling into sheets or strips, reaches an ultimate strength of 150,000 to 250,000 lb per sq in. Mr. Budd described its characteristics as a structural material and its use in railroad equipment.



TANK-CAR OUTLET AND SAFETY-VALVE TESTING EQUIPMENT

Lawford H. Fry pointed out briefly some of the service stresses to which railroad equipment is subjected and the essential characteristics that materials of construction must have to meet these conditions. He spoke particularly of boiler steels, steel-casting alloys, forgings, and bearing metals.

A SUMMARY

What conclusions may be drawn from the sketchily presented evidence taken from the record spread out before the A.S.M.E. Railroad Division at Chicago?

First, it seems to be beyond doubt that the criticisms directed against the railroads for lack of technological progress have little basis of fact once the record is examined. Hidden away from the attention and comprehension of the ordinary citizen have been important and far-reaching developments and fruitful researches for the benefit of the railroads and the public they serve. Criticism on grounds of progressiveness will have to be made in other than technological fields.

Second, it is evident that there exists between the railroads and industry a spirit of cooperative understanding of problems of mutual interest Each industry is and has been conducting research that the railroads themselves could not duplicate except at an enormous and unnecessary expense. For as Mr. Bilty pointed out, the business of the railroads is transportation, and the responsibility for developing equipment rests largely with the manufacturers who cater to the railroads' needs. The railroads' part is to stimulate industry to provide the new and improved equipment, devices, and materials, to bear their share of the burden of development, and to provide the practical service testing laboratory in which new ideas may be tried out and perfected. This has been the traditional method; it bids fair to continue so to be on the strength of its past success.

Third, there are evident from the record certain general tendencies in railroad technological developments, as follows:

1 Cars of lighter weight and greater strength and safety.

2 Development of standard equipment that can be interchanged with maximum ease and maintained at minimum expense.

3 The use and further development of materials which can be used to produce lighter, better, and more economical equipment that will have greater capacity or power per unit of weight and that will be simplified as to design and number of parts.

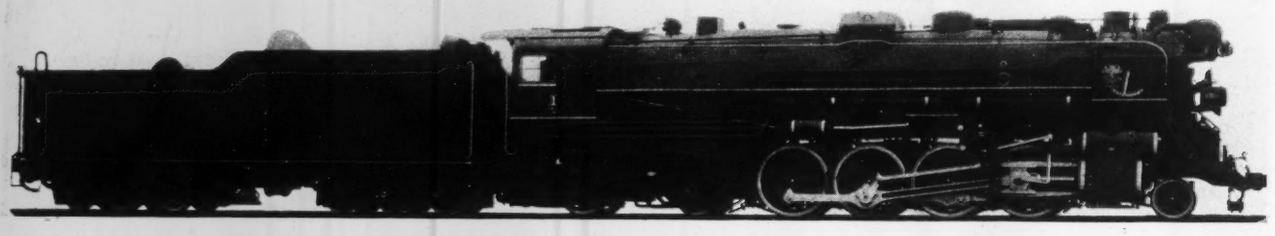
4 The development of boilers for higher pressures, leading to the more economical generation of steam, and to greater power per unit of weight of the locomotive.

5 The development of valve gears that will provide greater efficiency in the use of steam.

6 The development of locomotives that are so designed and equipped that they reflect the best of power-plant experience in mobile units.

7 The development of equipment, materials, and operating practises that will reduce wear and tear on rails and track structures and thus reduce the operating expense.

8 The development of accessories (such as anti-friction bearings) that will facilitate the movement of railway equipment with a minimum expenditure of power and money.



EIGHT RAILROADS COOPERATED IN THE ROAD TRIALS OF LIMA LOCOMOTIVE A-1 FOLLOWING DEVELOPMENT WORK ON A BASIC DESIGN FOR THE 2-8-4 LOCOMOTIVE

What's Happening to the CORPORATION?

A Review of a Recent Book on the Modern Corporation and Private Property

By W. D. ENNIS[1]

CRITICS CONDEMN the novel with a purpose. This is a treatise[2] with a purpose. It points out two things: (1) ultimately, an impending social transformation; (2) immediately and causative, "the power of confiscation of a part of the profit stream and even of the underlying corporate assets by means of purely private processes, without any test of public welfare or necessity. As they stand, these powers are nominally uncontrolled." The confiscation spoken of is not that which is familiar in communist terminology; it is a confiscation of stockholders' profits, etc., by those other than stockholders. Briefly, the more immediate purpose of this book is to demonstrate that the investor in a corporation is not protected in his investment. The authors make out their case, for which the public was more or less prepared. With this intent they have deliberately not produced an elementary textbook on corporation finance.

The lay reader will here find "stop" and "detour" signs. He will learn to beware of complex capital structures and "classes" of stocks, of paid-in (capital) surplus, of new corporations, including most mergers and holding companies, of Delaware corporations, of non-cumulative preferred stock whether or not participating. He will be told that many recent devices, stock warrants, for example, are of untested legal validity. He will be advised never to buy a security without reading the certificate of incorporation—a counsel of perfection, since most buyers rely on the flotation circular or, more frequently, on market appraisals, and only the "Philadelphia lawyers" who write them can understand or interpret the certificates.

On the other hand, the "boob" investor will learn here that a mere application for listing on the New York Stock Exchange presupposes a degree of respectability; that flotation circulars generally tell the truth, though not the whole truth; that "the integrity of the (public) accountant and the soundness of his method are the greatest single safeguard to the public investor;" that standards of "decent accounting" "are not yet embodied in the law;" that the New York Stock Exchange has developed year by year a series of rules, steadily widening in scope, whereby accurate appraisals of security values are facilitated; that in certain cases this Exchange has laid down specific and stringent requirements, "notably its insistence that investment trusts shall publish their portfolios;" that the Morgan firm has steadily refused to make use of the hedging artifice, "Statements made in this circular, though taken from sources believed to be reliable, are not guaranteed," assuming full responsibility for statements made.

Such investors, and others who may not have read the Splawn report, may be surprised to learn that the Van Sweringen brothers own, directly and indirectly, less than one per cent of the capital of any of the railroads, the Nickel Plate, the C.&O., the Wheeling and Lake Erie, the Pere Marquette, the Erie and Hocking Valley, and less than two per cent of the Missouri Pacific. The brothers' total investment of less than $20,000,000 gives them control of assets exceeding two billion dollars. This situation is not abnormal. Officers and directors of steam railroads as a whole own 1.2 per cent of common and 0.1 per cent of preferred stock of their roads. Nor is this condition confined to railroads. In gas companies, management holdings are 1.4 and 0.4 per cent, respectively. For "all industries" the figures are 10.7 and 5.8 per cent. Only in farming, lumbering, and construction do management holdings of common stock equal or exceed a majority interest. Cities Service Company common stock has 1/20 vote per share. "In 1929 this corporation sold to H. L. Doherty and Company one million shares of a $1 par preferred stock. Each share of this stock was entitled to one vote in the election of directors. . . . Twenty-seven per cent of the (total) votes could be cast by the million shares of preferred. Since the other classes of stock were widely distributed . . . a million dollar par value of stock held virtual control over assets of approximately a billion dollars."

Considering our 200 largest corporations at the beginning of 1930, 58 per cent of aggregate wealth was under informal management control, 22 per cent under technical legal-device control, e.g., voting trust, and 14 per cent otherwise under minority control. Only 2 per cent of such wealth was controlled by the stock-

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[1] Alexander Crombie Humphreys Professor of Economics of Engineering, Stevens Institute of Technology, Hoboken, N. J.

[2] "The Modern Corporation and Private Property," by Adolf A. Berle, Jr., and Gardiner C. Means. The Macmillan Company, New York, 1933. Cloth, 6 1/4 × 9 1/4 in., 396 pp., $3.75. Prepared under the auspices of the Columbia University Council for Research in the Social Sciences acting on behalf of the Social Science Research Council of America.

holders themselves, acting through a bona-fide majority. Fords and Mellons are rare in corporation finance.

And if these facts are new to the layman, what will he think of the rule prevailing in most jurisdictions whereby preferred dividends may be withheld, although earned, in order that a surplus may be built up out of which common dividends are later paid?

EVOLUTION OF THE CORPORATION

To show the quasi-logic underlying such facts, and their implications, the authors have traced the evolution of the corporation idea. Corporations were originally created by special statute, usually in association with a specific franchise, as, for example, to build a bridge. The real privilege now granted is that of corporate entity, involving perpetual succession. Thus the individual can invest a particular and limited amount of his total capital. State laws were originally framed for the protection of corporation creditors rather than investors. "Shareholders were supposed to be capitalists reasonably able to protect themselves." Nevertheless, the investor was not wholly ignored; the enterprise was defined and limited in scope. Again, there were certain safeguards against dilution of interest.[3] A par value was set on each share of stock, and each and every share was supposed to be sold at this par price. A rigid capital structure was prescribed; so many shares of common and preferred stock, each of prescribed par value. Residual control of important matters, e.g., a change in capital structure, was reserved to a large majority or even a unanimous vote of stockholders. If new stock was issued, the existing stockholders had an option ("preemptive right") to purchase it. Management was thought of as a group of agents running the business for the stockholders. Its position was like that of the captain of a ship at sea.

This condition of things has gradually broken down, "always in the direction of granting to the management or to a small proportion of the owners a wider latitude of power." Such transformation "roughly accompanies the appearance of large-scale production and the growth in number of shareholders."

Modern corporation charters are granted under general incorporation laws, the first of which was enacted in New York in 1811. These charters rarely define and limit the scope of corporate activities, except in the broadest and vaguest terms. The first modern corporation law was that of Connecticut, 1837. This was the beginning of the end of charters as special contracts with the legislature. Stockholders are now drawn from the general investing public. The organizers aim and plan to retain, or separately dispose of, control. Thus, leaving only a comparatively small amount of their own capital in the project, they reap the fruits of control therein, while "enabled to go on to organize further similar corporate units." Emerges the promoter!

[3] Dilution: If I pay $100 a share for stock and you are later charged only $50, my interest has been *diluted*. Even though the company's earnings have fallen off so that the market value of shares has dropped to $50, I am injured. Your participation in liquidation is the same (per share) as mine.

Control, as separated from majority ownership, is immensely facilitated by modern proxy mechanism representing absentee stockholders. This mechanism "has thus become one of the principal instruments not by which a stockholder exercises power over the management of the enterprise, but by which his power is separated from him." Through the skilful handling of proxies (and very little skill is required), "where ownership is sufficiently subdivided, the management can become a self-perpetuating body even though its share in the ownership is negligible."

The principle that stockholders might remove directors at will has now almost completely disappeared. A charter may be amended in any particular, in most states, by a two-thirds vote; in some states, by a bare majority. Thus, by a majority vote, and even by a minority control, a $100 preferred stock paying 8 per cent might be changed to a $50 stock paying 3 per cent. We are moving toward the principle that "*all* controlling powers of shareholders may be more or less permanently delegated." Stock may be issued for property or services as well as for cash; and what about dilution then? For management fixes the value of both property and services. Generally, a valuation made in good faith cannot be set aside. "At its extreme, this rule would mean that the more incompetent the board of directors, the greater their power to dilute stock; since their overvaluation, however foolish or inequitable, would nevertheless be innocent."

CORPORATION PRACTISES

As if this were not bad enough, no-par stock was invented in 1912. Usually, it "may be issued for such consideration as the directors in their discretion may determine." Law and practise are, however, "imposing certain checks on this power to dilute." One may hope so!

Stock issued for property is not subject to the preemptive right (*supra*). And the right can be avoided "by merely authorizing in the charter many more shares than were to be issued at the commencement of business." In many charters, the stockholder waives his preemptive right in advance.

Fixing a par price for stock does not safeguard against dilution in cases where the asset value (book value) exceeds the par value. "The corporation utilizing all of the modern devices will grant to its directors a substantially untrammeled power though the issue of stock and the determination of its price to regulate the asset value behind each share."

"The share of stock as at present known, while it represents in a sense a participation in corporate assets, does so subject to so many qualifications that the distinctness of the property right has been blurred to the point of invisibility. . . . A stockholder's right lies in the expectation of fair dealing rather than in the ability to enforce a series of supposed legal claims. . . . In almost no particular is he in a position to demand that they [the directors] do or refrain from doing any given thing."

The development of corporations, however rapid, is

probably not even yet at its zenith. They grow in number, in size, in number of stockholders. Some of them have more stockholders than employees. Large operations require corporate organization; and where such organization is provided, other large operations are sought and carried on. Some of the least progressive and least socially minded industries are least apt to be corporately organized (page 15).

The book features a special study of very large corporations. The group reporting gross assets less depreciation exceeding 100 million dollars forms a statistically separate group. (There are comparatively few corporations having assets between 50 and 100 million.) The authors remark that these superorganizations are characterized by excessive debt. But it might be urged that railroads and other public-utility companies have heavy debts, not merely because they are large but also because their capital turnover is low. The supercorporations, about 200 in number, control a large part of the economic assets, annual production, etc. of the nation. There is much interlocking of management and control. The 200 corporations have 2000 directors, many of them, no doubt, inactive. It looks as if less than 1000 men have effective control of nearly 100 billion dollars of assets; one-fourth or one-third the country's total wealth. These 1000 men constitute our economic oligarchy. The assets of these corporations increased nearly 20 billion dollars from 1922 to 1927. They survive; at least, of the 200 largest in 1919, only two had liquidated or otherwise disappeared by 1928. One hundred seventy-seven were apparently still included among the 200 largest of the latter year.

THE MULTITUDE OF STOCKHOLDERS

Why are there so many corporate stockholders? One reason is that with income surtaxes as they have been, corporate securities have become investments for the poor instead of the rich. What choice has the modest saver? Investments must be in corporate securities, real estate, or government bonds. Deposits in savings banks or with insurance companies go into one of these three channels. They have nowhere else to go. "Over 55 per cent of the growth of the [200] large companies has been made possible by the public offering of additional securities." Probated estates in 1928 indicated that 58½ per cent of investments are in corporation securities. In 1927, 46 per cent of the dividends received were paid to persons not in the group of 100,000 individuals receiving the largest incomes. This proportion was almost twice what it was in 1916. The period of rapid increase was from 1916 to 1922. The authors estimate that in 1929 the number of corporate stockholders in this country was between 4,000,000 and 7,000,000, which would seem to imply the representation of perhaps one-fifth to one-sixth our entire population. Apparently, each of these persons held securities in something over three corporations, on the average. And the proportion stated does not include those millions of persons whose money in savings banks, etc., is invested in corporation stocks or bonds.

The book does not settle statistically the question, How fairly are these small investors treated? "The expectations of bondholders, preferred stockholders, or common shareholders must all be satisfied to some degree if an enterprise is to grow." They have been unsatisfied since 1929. This might not be fatal. Flagrant abuses such as the book describes may be. The "boobs" seem to have come back in the market in 1933; but perhaps they would not have come back in the absence of a determined program of inflation. These, however, are the reviewer's reflections.

WHO GETS THE PROFITS?

Economists traditionally ascribe interest to capital and profits to management. Accountants give salaries to management and profits to stockholders (capitalists). The dilemma has never been resolved. The present book insists on the recognition of three instruments or agencies in the corporation: *ownership*, vested in stockholders; *control*, perhaps, nay, usually, by a small fraction of the stock; and *management* as the tool of control. A convenient hypothesis is that corporation organization has for its purpose the placing with one individual or group the largest possible amount of other people's money. The divorce of ownership from control is the central feature of this book. Control has been extra-legal, and even now the law scarcely attempts to deal with its major activities. When control is attacked, its war expenditures are financed out of the corporation treasury. Thus the corporation problem and the problem of government are alike, with control analogous to the "machine." The private citizen is protected by a Bill of Rights. The small stockholder is without protection. Both face the problem, How make a sound popular will effective?

What is the objective of control? Perhaps, like Alexander's, more worlds to conquer, the authors' shrewd suggestion. If profits are the objective, then the interests of control are necessarily and inherently adverse to those of ownership. Thus, during 1900–1915, control wrecked certain corporations. Worse still, control competes with its stockholder-partners. It has information which they do not possess; yet it trades with them on the securities markets. Profits are reward for risk and administrative efficiency. Hence, stockholders as such, who undergo risk, have a claim. But has not control, which performs the administration, also a claim? "The controlling group is in a position to serve its own interests." It administers, initiates. Otherwise, "individual initiative no longer exists."

Thus we are in the presence of a change. In theory, the corporation was an industrial democracy, an assembly of persons of limited means, cooperating in a giant enterprise to be managed by agents chosen by the owners. In modern practise, we have an oligarchy—a self-selected group of insiders who mobilize the savings of the public but themselves occupy a position of control not warranted by the magnitude of their own investments. Warranted, then, by what? Shall we say by divine right?

Now note this fine point; that, in most jurisdictions, "directors are trustees and fiduciaries for the corporation only; but as the corporation is a separate entity from the stockholders, they are under no duty to the stockholders as individuals. Since buying and selling stock from or to a shareholder is a transaction between individuals, the director is under no duty to the shareholder to disclose his information, or to avoid placing himself in an obviously adverse position."[4]

Basically, a director may not trade with the corporation, e.g., sell goods to it; but "charters commonly include waiver of this director's disability," and "the charter of the Dodge Brothers, Inc., a Maryland corporation . . . provided that a director should not be liable for secret profits even though he had failed to disclose to his fellow directors that he was interested in the transaction on which he had voted." The authors regard such clauses as of doubtful legal validity, if ever tested. But it costs a great deal of money to test them. No small stockholder is likely to undertake it.

So far, to sum up, the corporation is working badly, because inequitably. We need it, however; perhaps we cannot get along without it. Hence, we must learn to use it better. The authors, however, do not reach precisely this conclusion. In the concluding part of their treatise, they insist that ownership continually becomes more dispersed, while the power formerly associated with it but now separated from it becomes increasingly concentrated. What, then? The book proceeds:

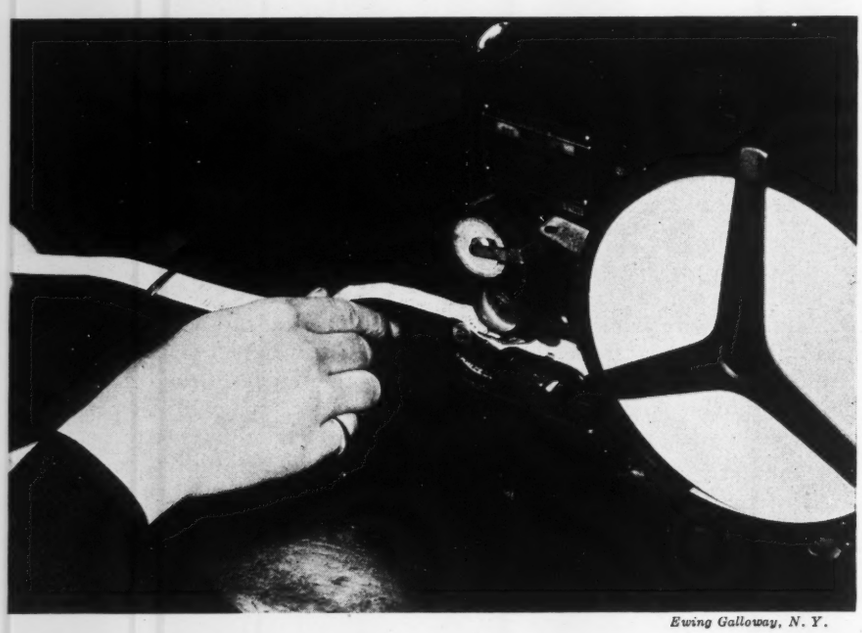
Control and management, although entitled to some diversion of profits, should be looked upon as fiduciaries. They must act conscionably, as under a common-law trust. But the complexities of corporation activity make fixed standards of conduct impracticable. There is an absolute lack of ability in the law to handle the problems involved.

The courts are "afraid" to interfere. This leaves ample (excess?) latitude for "control" to divert profits in its own favor. [Control operates like the "fee" system in sheriffs' and surrogates' offices; it seizes profits indirectly and hence excessively. Perhaps securities offered to the public should include only those of the fixed-interest type, leaving "windfall profits" for control. But some writers are advocating the opposite; that corporations should issue equity securities only.]

The separation of the two attributes, beneficial ownership and control, destroys private property as we now know it. We must recognize *active* and *passive* wealth. And still (quoting), the old concepts of private enterprise and individual initiative disappear. Moreover, is there not a law of diminishing returns for enterprise? "It is doubtful if the prospect of a second million dollars of income . . . would induce activity equal to that induced by the first million," implying, it would seem, that two opportunities, each to make a million, provide more stimulus to management than one opportunity to make two million; and, ultimately, that large corporations are inherently less efficient, or, at least, less enterprising, than small ones.

World history is the history of the mobilizing of power for the general good. Thus the medieval church, thus the modern state, and now, perhaps, the corporation. The owner is not entitled to all of the profits because he does not manage. Control is not entitled, because it does not own. The public may step in with a claim. Thus capitalism leads to communism just as socialism has led to fascism. "Should the corporate leaders, for example, set forth a program comprising fair wages, security to employees, reasonable service to the public, and stabilization of business, all of which would divert a portion of the profits from the owners of passive property, and should the community generally accept such a scheme as a logical and human solution of industrial difficulties, the interests of passive property owners would have to give way. Courts would almost of necessity be forced to recognize the result, justifying it by whatever of the many legal theories they might choose. It is conceivable—indeed it seems almost essential if the corporate system is to survive—that the 'control' of the great corporations should develop into a purely neutral technocracy, balancing a variety of claims by various groups in the community and assigning to each a portion of the income stream on the basis of public policy rather than private cupidity."

Mebbe so.



Ewing Galloway, N. Y.

[4] Carpenter v. Danforth, 52 Barbour, 581 New York, 1868.

PRODUCTION *and* PURCHASING POWER

A Study in Support of a View Expressed in the First A.E.C. Report on Economic Balance

By C. A. NORMAN[1]

THE first progress report issued by the Committee of the American Engineering Council on the Relation of Consumption, Production, and Distribution[2] was an epoch-making document and will probably go down into history, with the report of the Committee on Waste in Industry and Stuart Chase's book "The Tragedy of Waste," as a milestone on the road of industrial progress. The engineer may base his activities on scientific facts, but he is not interested in these facts for their own sake. He is interested in them as a basis and a means for attaining a definite constructive purpose. Usually he has to make decisions and take steps before complete scientific information is available for his guidance. In using science, he must learn to simplify and approximate; he must make the most intelligent analysis or forecast that can be made; but he must then be willing to face a period of experimentation before a new development can be called a practical success.

THE ENGINEERING APPROACH

If the engineer must resort to simplification and approximation in dealing with the exact sciences, much more will this be true in dealing with the social sciences.

The political economist philosophizes about economic phenomena as he sees them. The report on "Waste in Industry" conceived industry as an instrumentality for supplying human needs through human effort and assessed the efficiency with which this process was carried out in six important industries. Stuart Chase, using these and other data, came to the conclusion that if all waste were eliminated we could just about double the amount of good things and services made available for men.

Some engineers caught this vision. In *The Forum* for November, 1930, Ralph E. Flanders wrote:

"The engineer knows—all engineers know—that, if some omniscient dictator were installed as ruler of the United States, they could provide for him raw material, machinery, and trained labor sufficient to flood, bury, and smother the population in such an avalanche of food, clothing, shelter, luxuries, and material refinements as no Utopian dreamer in his busiest slumbers has ever conceived."

And in a paper before the Annual Meeting of the American Academy of Political and Social Science, on April 15, 1932, he said:

"In the problems which you have set yourselves to consider today and tomorrow is involved a new and unforetold stage in human development—the self-conscious direction of the mechanism of his economic and social life to ends of general well-being. The eye that has caught this vision is satisfied with no other. . . ."

Then came the depression. The immediate problem was no longer to march ahead to new Utopias, but to maintain the gains already made, and, if possible, prevent the world from collapsing in these periodic cataclysms which seemed to come in inescapable recurrence as a result of the operation of commercial processes.

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[2] MECHANICAL ENGINEERING, vol. 54 (1932), no. 6, pp. 415–423.

Gerald Young

This was the problem the Committee on the Relation of Consumption, Production, and Distribution, under the chairmanship of Ralph E. Flanders, set itself, and it dealt with it, to begin with, by characteristic engineering methods of simplification. Admitting the immense complexity of the problem, the first progress report singled out one cause of depressions as most fundamental, and proposed ways for dealing with this main cause. The analysis carried out was bold and courageous. Recognizing that profits and reserves were necessary for individual industrial enterprises, the committee did not hesitate to say that these surpluses, when not spent in new investments, constituted withheld purchasing power and hence made impossible the matching of consumption with distribution. The remedy was obvious, if the *form* of profit making were to be maintained. It consisted in the government's taking over undistributed surpluses by borrowing and taxation and using them for public works and services, when private-capital works expansion no longer could absorb them.

AMERICAN ENGINEERING COUNCIL'S REPORTS

The Committee's analysis and suggestions met with some detailed criticism, and in their second progress report[3] the members of the Committee cease to be engineers and appear as philosophizing economists. Reviewing forty alleged causes of business instability, they refuse to single out any one or any small number as most worthy of serving as bases for action; and instead of suggesting a line of action to follow, they simply list twenty-three suggestions made by others. The great visions of general affluence have vanished in the struggle with the depression. No schemes were considered of far-reaching economic organization intended to secure for everybody that well-being which would be possible if we made a better job of coordinating our industries for this purpose.

In neither the first nor the second progress report were the data given on which the conclusions were based. This is to be regretted. If these data had been furnished, interested persons could have made up their own minds as to the justification of the simplifications made in the first report, and could have formed an opinion as to the necessity for assuming the utterly negative and non-committal attitude in the second report. In MECHANICAL ENGINEERING, June, 1933, L. P. Alford, a member of the Committee, gives a statement of his personal attitude. This statement contains some positive suggestions. Yet, on the whole, it defends the attitude of extreme caution assumed by the Committee and gives no data for further conclusion.

PURPOSE OF THE PRESENT ARTICLE

It is the desire of the author of the present article to supply some such data; to call attention to some current fallacies, and, finally, to emphasize that the present depression may not be just another depression, but may, in fact, have in it fatal elements which may mean either the arrival of complete collapse or paralysis in the near future, or a gradual reversion to simpler forms of society, with a sad good-bye to that dream of affluence for all.

Should this be the fact, it is evident that the time for mere philosophizing on business cycles has passed. The time has come for social construction and reconstruction. Let us hope that the members of the Committee in their final report will meet this challenge with the courage and the boldness one might expect from men speaking as Mr. Flanders did before the American Academy of Political and Social Science.

DATA ON CONSUMPTION AND PRODUCTION

The problem is one of adjusting consumption to production.

Let us then begin with a table showing the increase in the production of various classes of physical goods between 1922 and 1929. The data are given in Table 1 and are taken from "Economic Tendencies," by Frederick C. Mills, published in 1932 by the National Bureau of Economic Research.

Who will consume this rising flood of commodities? In the New York *World-Telegram*, January 10, 1933, Prof. Harry Elmer Barnes, basing his statements on an analysis in *The Business Week*, makes it quite clear that the great majority of these consumers are persons of small means.

> The great majority of manufactured goods and agricultural products . . . are purchased by families with incomes under $3000, about three-

[3] MECHANICAL ENGINEERING, vol. 55 (1933), nos. 4 and 5, pp. 211–224 and 295–304.

fifths by families with incomes under $2000, and about one-fifth by families with incomes under $1000.

Families with incomes of $3000 and less paid 73 per cent of the total amount spent for consumers' goods and services, but had only 30 per cent of the total national savings. Families with incomes over $3000 paid only 27 per cent of the total amount spent for consumers' goods and services, but had 70 per cent of the total savings. Indeed, in 1929 some 28,000,000 families with incomes under $3000 spent $65,143,000,000 and saved $3,746,000,000—less than one-sixteenth of what they spent. The 513 persons with incomes of over $1,000,000 spent $87,000,000 and saved $1,045,000,000—twelve times as much as they spent and nearly one-third as much as was saved by 28,000,000 families.

The question then is: What happened between 1922 and 1929 to the aggregate income of persons of small means who consume by far the major part of consumption goods sold?

TABLE 1 INCREASE IN PHYSICAL VOLUME OF GOODS BETWEEN 1922 AND 1929

Year	Non-durable goods	Semi-durable goods	Durable goods (movable)	All movable goods	Goods and construction
1922	100	100	100	100	100
1923	108	107	127	112	110
1924	110	96	120	109	109
1925	110	109	140	117	119
1926	116	109	151	124	126
1927	118	117	136	123	125
1928	122	116	154	129	131
1929	124	122	172	134	134

NOTE: By "non-durable goods" is meant food and other perishable consumption articles; by "semi-durable goods," boots and shoes, textiles, rubber tires, etc.; by "durable goods," such things as automobiles, furniture, electric appliances, carpets, mattresses.[4]

TABLE 2 RELATIVE PURCHASING POWER OF VARIOUS SOCIAL GROUPS DERIVED FROM INCOME IN 1913 DOLLARS

Year	Total agricultural income	Total wages in manufacture	All wages	All salaries	Entrepreneurs and owners, less those in agriculture
1922	100	100	100	100	100
1923	111	117	115	117	110
1924	113	111	116	116	114
1925	116	112	121	120	119
1926	104	117	127	126	127
1927	111	116	131	139	132
1928	110	112	128	144	142

For basic data see King, pp. 77, 100, 112.

To help us answer the question asked, certain data on income movements are given in Table 2. These data have been derived from figures in "The National Income and Its Purchasing Power," by W. I. King, published in 1930 by the National Bureau of Economic Research. Unfortunately, the data do not go beyond 1928; yet they will probably suffice. They give relative income based on absolute income expressed in purchasing power with 1913 dollars.

[4] For source of data, see Mills, pp. 246, 270, 272, and 274.

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In comparing Table 2 with Table 1, we are struck with the fact that the relative increase in all wages seems to keep step fairly well with the relative increase in all goods produced, and the relative increase in salaries outruns this increase in production. Certain investigators have concentrated their attention on total agricultural income and the wage income in manufacturing alone, and have noticed how, between 1923, the year of recovery after the depression in 1921–1922, and 1928, the income of these two important groups remained practically stationary, while the income to property owners and entrepreneurs increased greatly. From this they have taken the attitude that no further proof was necessary to show that the mass of people with small income could not possibly buy back the steadily increased volume of goods they were producing. The figures so far given do not warrant such a conclusion, particularly when we realize that in 1927, the last year for which Mr. King gives a figure, the average income of salaried employees was only $2084 and that, in consequence, this group also contributed greatly to the number of persons with small incomes. The number of persons engaged in manufacturing and in agriculture actually decreased from 1923 to 1929, as shown on the former in Table 3. The income per person engaged in manufacturing went up, although not enough to enable the group to keep even with the increase in production. The increased number of people in various other occupations, however, gave a total relative rate of income increase apparently as great as the rate of increase in production. The increased production was due to the

increased productivity per worker, as is made clear in Table 3.

TABLE 3 PRODUCTIVITY AND NUMBER OF WAGE EARNERS IN MANUFACTURING

Year	Physical volume of production	Number of wage earners	Output per wage earner
1923	100.0	100.0	100.0
1925	102.4	95.4	107.3
1927	104.2	92.3	113.0
1929	113.0	92.6	122.0

From Mills, "Economic Tendencies," p. 290.

It is when we come to investigate the distribution of income between various income groups in the nation as a whole or in various industries that we perceive that the masses of the people could not possibly directly absorb the products they produced.

For 1928, according to King, the figures for the nation as a whole were as shown in Table 4. Table 4 is not

TABLE 4 ABSOLUTE AND RELATIVE SHARE OF VARIOUS GROUPS IN NATIONAL INCOME OF 1928

	Current dollars (millions)	Per cent
Total national income	89,419	100.00
Share of entrepreneurs and other property owners	38,296	42.83
Share of wage earners	32,235	36.05
Share of salaried employees	17,823	19.93
Pensions, compensations, etc	1,065	1.19
Total share of employees	51,123	57.17
Average annual earnings per wage earner (in 1927)	$1,205	
Average annual earnings per salaried employee (in 1927)	$2,084	

King, "The National Income and Its Purchasing Power," pp. 74 and 80.

conclusive, since under entrepreneurs and property owners are included also farmers, shopkeepers, etc., whose annual earnings are small.

The information becomes more definite if it applies to individual industries. Two examples are given in Table 5. Unfortunately, this information appears to

TABLE 5 ESTIMATED APPORTIONMENT OF THE ENTIRE REALIZED INCOME RECEIVED BY INDIVIDUALS FROM CERTAIN INDUSTRIES

Percentage of income going to	In factories, per cent		In private electric light and power, per cent	
Profits, rents, dividends, and interest on funded debt	(1925)	15.25	(1922)	52.96
Salaries of officials and managers	(1919)	9.09	(1922)	5.62
Clerical salaries	(1919)	9.00	(1922)	14.09
Wages	(1925)	64.57	(1922)	27.33

From King, "The National Income," pp. 84–85.

be available only for isolated years and does not cover all industries in the same year. Nevertheless, there is little doubt about the lesson taught.

To make it quite clear what part of the total value produced is distributed directly as purchasing power to humble persons concerned in producing it, we should add to the percentage going to profits, rents, etc., also the percentage set aside as corporate reserve. The estimate of this varies a good deal. Berle and Means[5] put the average for the six years from 1922 to 1927 at 29.4 per cent for all non-financial corporations and at 38.5 per cent for 108 of the 200 largest corporations.

King[6] gives estimates considerably higher. In any case, it is hardly excessive to assume that one-fourth to one-half of the value produced by the masses of the producers is withheld from them in the form of dividends, interests, corporate surpluses, etc. It is also a well-known fact that by far the major portion of dividend and interest payments goes to people of comparatively large income. On the basis of Federal income-tax returns for 1929, Berle and Means state that 73.7 per cent of corporate income tax returns was received by 597,003 persons reporting taxable income of $5000 or more. There are some 4 to 7 million persons owning stock in this country. However, in 1924, 37 per cent of the stockholders of the American Telephone & Telegraph Co., for example, owned five shares or less, and received less than $46 in dividends from this company, probably averaging less than $25. The average employee stockholder may own, perhaps, $1000 worth of stock and receive in dividends something like $60 per year.[7]

If we add to that portion of the income which goes to ownership of various kinds that which goes to comparatively well-paid officials, it certainly is not excessive to state that as a rough average one-third of all income goes to persons of considerable means and not more than two-thirds to the masses of the consumers. In consequence, since the rich save a large part of their income, the only way in which all the goods of which the total income represents the value can be bought is by their investing their savings, ultimately adding to the general purchasing power. One such investment is in plant expansion. The bricklayers, the stone masons, the structural iron workers, the builders of railways and shop equipment thus get their share of the general purchasing power.

INDIRECT DISTRIBUTION OF PURCHASING POWER

That this is actually what in large measure happened between 1922 and 1929 can be seen from Table 6, in which total stock and bond issues by corporations are compared with the amount of dividends and interest paid out in the same year.

Table 6 shows that, roughly speaking, new investments balance the dividend and interest payments to individuals. One might feel that little more need be

[5] "The Modern Corporation and Private Property," p. 360.
[6] "The National Income," p. 285.
[7] "The Modern Corporation and Private Property," pp. 59, 60, and 372.

TABLE 6 DIVIDEND AND INTEREST PAYMENTS AND STOCK AND BOND ISSUES, 1922 TO 1929

(All Figures in Millions of Dollars)

Year	Corporate dividends paid to individuals[a]	Industrial interest paid to individuals[b]	Total corporate stock and bond issues[c]	Foreign issues (corporate)	Foreign government issues
1922	2,634	1,502	3,073	128	431
1923	3,299	1,568	3,233	67	243
1924	3,424	1,639	3,839	317	778
1925	4,014	1,678	4,738	515	645
1926	4,439	1,792	5,300	725	514
1927	4,766	1,933	7,319	812	777
1928	5,157	2,051	7,818	887	651
1929	5,763	?	10,026	649	68

[a] From Mills, p. 490. [b] From King, p. 186. [c] From The World Almanac after *The Commercial and Financial Chronicle*. The foreign issues listed as corporate are included in the total corporate issues.

said, and that there would be little reason why the Committee on the Relation of Consumption, Production, and Distribution should not stick to the analysis and recommendations in the first progress report. However, we may investigate a few other suggested means of indirect income distribution. Table 6 reminds us of the importance of foreign investments. Something like a billion dollars a year went abroad in the period between 1922 and 1929. Much of this money was used to buy American products. Since the payment of these foreign loans is somewhat uncertain, one may say that American capitalists supported American workers in order to donate machines to foreigners. The process was rather suicidal in the long run. Not only did it stop when it became quite clear that payments would not be made, but the modernized and rehabilitated European factories created a cut-throat competition for American products in foreign markets, so that we lost not only the market artificially created by our own loans, but also other and more legitimate markets. Many have seen in the collapse of the foreign market the main source of the depression. Actually, exports receded from 5241 millions in 1929 to 3843 millions in 1930.

Another way to maintain temporarily a fictitious balance is by the expansion of instalment buying. It is quite clear that in the "state of continuity" when instalment buying is not increasing it is no aid whatever. People are simply reducing their buying in one direction to pay off instalments in another. The total amount of buying and buying power is not enlarged. As long, however, as the total amount of selling on the instalment plan is increasing, the people are constantly receiving a greater value in goods than they give payment for, and workers are therefore being maintained out of savings available to the employers. According to statements in "Recent Social Trends" (p. 862), instalment selling increased from less than a billion dollars in 1910 to 7 billions in 1929. There were years when it did not increase. However, it increased by about 2 billions between 1927 and 1929. In this period, then, there was delivered to the people about 2 billion dollars, worth more of goods than they were paying for.

A shrinkage in the volume of instalment sales is just as serious an unbalancing force as an increase is a balancing force. Those who are producing goods for instalment sales lose their work and their purchasing power; and in addition there is a deficiency of new credit to balance payments for goods already purchased.

The drop in instalment sales from 7 billions of dollars in 1929 to 5 billions in 1930 was therefore unquestionably an influence which seriously intensified the depression. It is possible that overdone high-pressure salesmanship in 1929 and difficulty in collecting instalments were responsible for some of the recession in 1930. In 1931, a majority of business leaders and economists questioned by Professors Caldwell and Younger in connection with the author gave as their opinion that high-pressure salesmanship had been overdone.[8]

CAUSES OF DEPRESSION

Be this as it may, certainly the major cause of the depression was the increasing realization, in 1929, that factories had been overexpanded to an extent which no longer made it possible for them to run at capacity, even in extreme boom times. The second progress report of the Committee on the Relation of Consumption, Production, and Distribution cites the United States Department of Commerce to the effect that in several important industries there was even, in 1929, an unused capacity of from 10 to 30 per cent. Much higher figures have appeared from other sources. Harry W. Laidler, in his little pamphlet, "Unemployment and Its Remedies," cites Ethelbert Stewart, United States Commissioner of Labor Statistics, to the effect that cement mills have a developed capacity of 260,000,000 barrels against a demand of 150,000,000 barrels, and cites Chase to the effect that we have a shoe-producing capacity of 900,000,000 pairs of shoes a year against a demand of 300,000,000, an automobile plant capacity of 8 million cars against a maximum production so far of less than $5\frac{1}{2}$ million, and so forth. Nor is overcapacity confined to factories. Mines, office buildings, hotels, and many other things are just as seriously overbuilt.

We find, then, total corporate security issues in the United States alone decreasing from 9377 millions in 1929 to 4956 millions in 1930. Such a reduction is equivalent in plant expansion to the loss of income by four million workers.

And now comes the socially most pernicious part of the performance of business in this calamity. After some resistance, it begins to cut and discharge labor wholesale, i.e., cuts its market from under its feet, while at the same time it goes into surplus to maintain dividend and interest payments to the rich already at a loss to know where to invest the money coming to them.

Manufacturing wages drop from 11.6 billions in 1929 to 4.9 billions in 1932. Simultaneously, dividend and interest payments actually *rise* from 7.6 billions in 1929

[8] See Engineering Experiment Station Circular No. 26, "Economic Attitudes in Industry," published in 1932 by The Ohio State University.

Wendell McRae

to 8.6 billions in 1930, and remain at 8.4 and 7.0 billions in 1931 and 1932.

BUSINESS AND EQUALIZATION

It is such a complete lack of social intelligence as this that makes one doubt whether the business motive can ever be trusted to take care of large-scale social development. The point is that business measures, and perhaps must measure, its success and stability in profits, the very thing that makes it impossible to balance consumption and distribution in a closed social system. This will not be cured by President Roosevelt's industrial associations as long as their main incentive is the maintenance of a high profit level. Theoretically, the profit accumulations may, of course, be taxed or borrowed away as depression threatens. But if this is to be done by legislative action, one may be almost sure that there will be delays and resistance sufficient to allow major dislocations to develop before anything really effective is done. On the other hand, if a super-executive is entrusted with the task of keeping the economic system balanced, then it is just as well to keep profit down to a level corresponding to a sound and rational continuous expansion of industry, i.e., to the natural increase in population and a systematically raised standard of living and social achievement.

With such a supervision, we shall, in fact, have left traditional capitalism and the competitive system behind and have entered on an era of consciously directed and systematized social progress. Let it be said at once that only in this way can we hope to reach that general affluence which our productive capacity has made some of us visualize. Unregulated competition and profit seeking will inevitably lead to such a duplication of facilities, such a waste of human effort, and such a production of harmful and useless things that real well-being for all citizens is not possible.

It is, therefore, well to conclude this review by investigating to what extent the present depression may be considered just another depression, or to what extent it must be considered a new phenomenon which will lead to consequences not found after earlier crises.

A NEW ERA

In an address delivered at the Wharton Alumni Institute, in Philadelphia, on March 23, 1933, Dean Wallace B. Donham, of the Harvard Graduate School of Business Administration, had the following to say:

"This depression is serious because the framework of society on which individual business must function rocks on its foundation. . . . This depression is qualitatively different from any which has preceded it."[9]

It may be well to list some of the situations which justify such a statement.

In the first place, even as late as 1900, 61 per cent of the population of this country was rural. In 1930, only 43 per cent was rural and only 20.5 per cent actually lived on farms. The rest lived in small communities. A farmer, however, while of course he may be seriously inconvenienced by a depression, does not become idle, and still retains many ways of keeping himself alive. On the other hand, a city dweller without a money income is cut off from means of livelihood altogether. In this depression, then, the specter of mass starvation has appeared in this country as never before and from one-tenth to one-fifth of the population has had to be supported by public relief. If the depression deepens this problem might well become unmanageable. As Dean Donham says, "Fifty million people cannot support seventy-five million ineffectives."

NO LONGER A FRONTIER

In the second place, there is no longer a frontier. Up to 1890, or even somewhat later, a man could have 160 acres of good agricultural land for nothing. This was riches compared with European peasant conditions. No wonder that socialism or other subversive ideas never took a strong hold in this country. In Europe, the poor man could hope for relief only by encroaching on the privileges of the rich. In this country, with free land in abundance and the main body of the population agricultural, a man could join a class of fairly well-to-do people simply by his own effort and initiative. Now, however, free farm land is gone. On the other hand, the world's markets are oversupplied with farm products. A man cannot now go out on a farm without some capital, and without adequate training and skill he cannot possibly expect to make a good living where so many experienced persons are meeting great hardship. The "back-to-the-lander" nowadays, if he manages to keep himself alive at all, will sink to the level of the most meager subsistence farming and, in so doing, he

[9] See *Harvard Business Review*, April, 1933.

will intensify the difficulties for those who have hitherto been farmers on a commercial scale. In no case does the back-to-the-land movement help to make available to people that comfort and affluence which modern technology might supply. It is distinctly a retrogression, a renouncing of that promised land which modern engineering was about to open for us.

In the third place, this depression is different on account of the slowing up of population growth. From 1790 to 1860, the rate of population growth held almost steadily at about 3.5 per cent per year. By 1900, it was down to 2 per cent, and by 1930 to about 1.5 per cent. The likelihood is that it will dwindle to practically nothing and perhaps even be converted into a decrease by 1960 or 1970. This, however, robs our industry of an almost automatic cure for overexpansion. In earlier years, a factory capacity overbuilt to the extent of 30 per cent would be just about right 10 years later. This automatic adjustment is now gone. Only by steadily increasing the purchasing power of the deep layers of the population can overexpansion be compensated for. A reduced standard of living such as that caused by underemployment and the back-to-the-land movement, therefore, acquired a seriousness which it did not have in earlier days.

INCREASED PRODUCTIVITY AND EMPLOYMENT

In the fourth place, the increased productivity per worker means that even industrial expansion no longer creates increased employment. Table 3 shows that from 1923 to 1929 factory production went up while the number of workers actually went down. Also the farm population dwindled, while the physical volume of most farm products went up. This is an entirely new phenomenon. Between 1899 and 1914, the number of wage earners in manufacturing increased 36 per cent, and between 1914 and 1923, 30 per cent, although the productivity per wage earner simultaneously went up. A similar situation prevailed in farming. There is now a displacement of workers from these great industries rather than an accretion.

Douglas and Director[10] estimate that even in 1929 there was some 2 million unemployed. In fairly good times, the majority of those displaced may find employment in other occupations. Much has been made of the large development of new services in the 1920 decade—garage work, filling stations, repairmen for refrigerators and radios, restaurant and tourist services of various kinds, amusements, etc. However, Douglas and Director[11] cite several studies indicating that workers released by technological advance are likely to be idle for months or even years; that the new employment they may find is not usually as remunerative as the one they lost; and that when the release occurs at the age from 45 years up there is a great chance that they will never find employment again. All this is extremely intensified when a depression sets in. It is now generally held that new improvement and more severe selection of workers will cause some 5 million workers to remain unemployed, even if comparative prosperity returns. All told, technological unemployment certainly works in the direction of decreased purchasing power, waste of the labor power of those displaced, and prevention of higher standards of living.

Gerald Young

INFLEXIBILITY OF PLANTS

In the fifth place, factories built for modern quantity production are not able to operate well at a reduced rate of output. They are inflexible. If the demand for the article they are intended to produce slackens, they cannot readily be converted to producing something else.

All told, then, it is clear that we have a situation differing in very important fundamentals from previous situations. We have a social machine which requires delicate adjustments to function well and is not automatically self-adjusting. With careful planning and control, it can, unquestionably, be made to produce that affluence for all that Mr. Flanders visualized. Without that direction, it is now subject to a multitude of influences which will make it spread havoc rather than wealth.

We can allow ourselves to drift, in which case we shall probably gradually drift back toward greater penury, increasing difficulty of using our modern inventions, and stagnation all around. Or we can resolutely acknowledge that a social machine as intricate and as delicately balanced as ours has to be, if it is to do for us what we have dreamed of, must be deliberately and consciously run by a body of experts. We are far from having available such a body of experts yet. Some of the measures proposed by the national Government just now are almost in the nature of economic legerdemain, interesting enough to talk about in the classroom but almost sure to hurt as many groups as it will help.

It is only when men determined to provide for society the greatest possible amount of comfort and affluence are allowed to do this in the most direct way possible that we can hope to see this end realized to the fullest extent possible with our present technical means.

[10] "The Problem of Unemployment," Macmillan, 1931, p. 20.

[11] For statistics see "The Problem of Unemployment," pp. 147, 148, 149. The figure for those over 45 years of age who were not again employed is 30 per cent.

CONDENSER-TUBE CORROSION[1]

TWO REPORTS on the corrosion of condenser tubes, "The Relative Corrosion of Some Condenser-Tube Alloys" and "Relative Corrosion of Some Non-Ferrous Alloys by Impingement Attack," both prepared by John R. Freeman, Jr., and A. W. Tracey, of the Technical Department, American Brass Company, were presented to the A.S.M.E. Special Research Committee on Condenser Tubes at the Annual Meeting of The American Society of Mechanical Engineers, December, 1932. The original manuscripts of these reports, from which the present abstract has been made, are on file in the Engineering Societies Library, New York, where they may be consulted. The Committee hopes that the overall results will be published when the tests are finally completed.

The tests that are being made by these authors are to determine the relative life of various condenser-tube alloys. Both papers here abstracted are in effect progress reports, and the tests will be continued for an extended period.

The first paper gives results of tests of tubes in a small 16-tube "condenser," through which aerated sea water is circulated continuously at 120 F at about 8 fps velocity. The paper describes fully the apparatus, test procedure, and methods of control, and gives complete analysis of the water and metals used. Photomicrographs of the metals and full-size photographs of the sectioned tubes, after 14 1/2 months' continuous operation, are also included. The progress report gives comparative results for the following eight alloys: Muntz metal, Admiralty, aluminum brass, Ambrac A, Ambrac B, cupro-nickel 10 per cent, cupro-nickel 20 per cent, and cupro-nickel 30 per cent.

The results are discussed by the authors as follows:

"The tubes may be divided into two quite distinct groups according to the nature and degree of corrosion, the alloys containing nickel showing superior resistance to the high-zinc alloys (Muntz metal, Admiralty, and aluminum brass). Of the latter, the Admiralty was in a distinctly superior condition. The marked plug-type dezincification that occurred in the aluminum-brass tube is of particular interest, the resultant pitting at some points extending almost through the tube wall. Except for this damaging dezincification, the tube appeared to have a very uniform and smooth protective corrosion film. It is also of interest to note that the dezincification was more or less scattered along the middle portion of the tube, the ends being peculiarly free from pitting. The reason for this is not clear. The companion tube still under test in the condenser shows an apparently similar condition.

"There is no marked difference in the appearance of the tubes of alloys containing nickel (cupro-nickels and Ambracs) with the possible exception of the 10 per cent cupro-nickel tube. The protective film of this tube appears to be smoother and freer from evidence of the slight etching shown by the other tubes. It is evident that a longer service run even under the severe conditions imposed must be carried out before definite conclusions regarding the probable relative merits of these alloys may be drawn."

The second paper describes tests made on 15 alloys with a 1/8-in.-diameter stream of hot, aerated, natural, and synthetic sea waters discharging perpendicularly against the specimens under controlled velocities of from 12.2 to 36.7 fps in individual tests. The metals tested were refinery copper, deoxidized copper, Muntz metal, aluminum brass, Ambrac A, Ambrac B, Admiralty (2 lots), cupro-nickel 10 per cent, cupro-nickel 20 per cent, cupro-nickel 30 per cent, Monel, aluminum bronze, Everdur, and red brass. The specimens were 3 in. square.

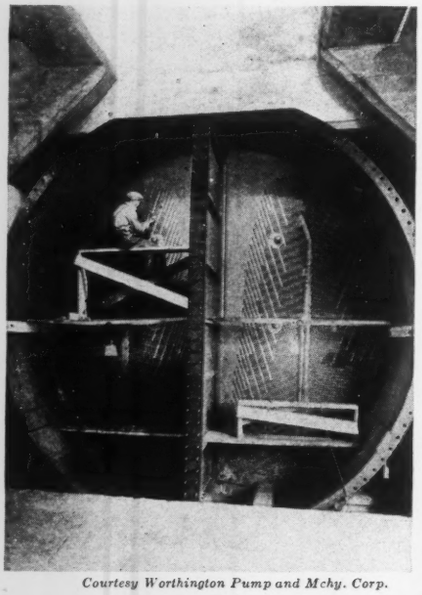
The number and variety of the observations make it impossible to condense the results into any brief summary which is accurate and complete. Among the more significant paragraphs from the authors' discussion of results are the following:

"The nature of corrosion under the test conditions varies markedly with the type of alloy and with the velocity of the impinging stream. Copper showed marked pitting at all but the lower velocities. The pitting was in general rather widely scattered over the surface of the metal and not confined to the impinged area. The high-zinc alloys (Muntz, Admiralty, aluminum brass) were remarkably free from pitting even at the higher velocities of test. However, all of these alloys dezincified to a more or less marked degree at the higher velocities of impingement attack. This freedom of pitting in alloys that dezincify was noted by May and the results presented here apparently confirm the fact that pitting by impingement attack does not occur in alloys that dezincify. The reason is not clear. The distinction should be noted, however, between pitting by impingement and pitting at dezincified areas such as the so-called plug type; the latter when present is, at least, equally destructive."

"The alloys containing nickel showed no general pitting over the surface of the specimen at the lower and relatively little at the higher impinging velocities. Pitting of these alloys at the impinged area varied appreciably. Moderate to severe pitting occurred in all of these alloys at an impinging velocity of about 32 fps and greater. At 17 fps the pitting, particularly of the cupro-nickels, was negligible.

"General pitting was quite definitely related to the velocity of the impinging stream. At the higher velocities, protective film was unable to develop over the surface of the specimen as partially occurred at the intermediate and lower velocities. The tests indicated that there may be a limiting or 'critical velocity of impingement' at which pitting attack begins for the individual alloys for the given test conditions."

The authors point out that while the velocities necessary to break down the protective film on the nickel alloys exceed the average velocities in commercial condensers, we do not know what *maximum* velocities we actually obtain in condensers. Very high local or transient velocities may be produced by turbulence and cavitation and the resulting impacts are variable and indeterminate.



Courtesy Worthington Pump and Mchy. Corp.

[1] Abstract prepared by W. F. Ryan, Stone and Webster Engineering Corporation, Boston, Mass. Mem. A.S.M.E.

PRACTICAL PLASTICITY PROBLEMS

By GEORGE M. EATON[1]

THE arousal of analytic interest in the phenomena of plasticity lays on the industries that wish to capitalize promptly on every advance of knowledge the responsibility of disclosing to the plastician the active problems in which he may be of assistance.

The first problem confronting the plastician in his effort to serve industry may well prove to be the analysis of methods for injecting into the minds of his potential customers sufficient of the plastic characteristic to permit them to give him a chance to show what he can accomplish.

When we think of the tremendous achievements of the steel industry in the plastic art, with practically no assistance along the line of strictly analytic plastic investigation, we see that we have no right to criticize those who doubt the ability of the pure mathematician to improve upon their practices. The burden of proof rests squarely on the shoulders of the plastician.

It is the purpose of this paper to meet the plastician half way by calling to his attention some of the problems in his line which are encountered in the steel industry. A complete mastery of his subject would unquestionably enable him to contribute greatly toward the solution of these problems. Whether or not his present knowledge is sufficient is a question which can be answered only by the practical results which he secures.

WHERE TO START THE ANALYSIS OF STEEL PLASTICITY

It is customary to start the discussion of steel plasticity by the immediate division of the problem into hot plasticity and cold plasticity, and to assume that those interested in the one problem have little or no interest in the other. This is a serious error, because the seeds of everything that happens to steel are planted in the ingot. The master plastician can become the master only by starting with the ingot, and following the complete history of the steel up to the point where he is to delve into a specific plastic problem.

Having determined where to start, the question arises as to how to start. The making of a logical start on the analysis of ingot plasticity is surrounded with so many obstacles that it is best to outline some of the alluring problems in which plasticity is a factor, before visualizing the stone lions which lurk along the trail which the plastician should follow.

PLASTICITY IN THE SURFACE OF STEEL INGOTS

From the standpoint of peripheral uniformity, no other form of ingot could equal one of truly circular cross-section. And yet large, truly circular ingots are unknown in any heavy steel production, because of the plastic limitations of the surface material. As a large circular ingot cools, the rigid hoop tension at the surface exceeds the ultimate strength of the hot metal, resulting in cracking and bleeding.

Much has been accomplished in developing the shape of the cross-section of ingots, resulting in the improvement in the surfaces of ingots and blooms. This work was necessarily done largely by cut-and-try methods with the guidance of some knowledge of plastic tendencies. But there is plenty of room for improvements to be worked out by the analytic plastician.

The study of plasticity problems carries us immediately into the field of rheology, and here help is needed. We demand in no uncertain terms the best assistance the rheologist can give in throwing more light of a fundamental nature on this vital subject. The analytic plastician is the logical interpreter to bridge the gap between the rheologist on the one hand and the metallurgical and mechanical engineer on the other.

PLASTICITY IN INGOT MOLDS

Indivisibly associated with the shape of the ingot is the influence of this shape on the ingot mold, the life of which is determined by the plastic characteristics of the material of which it is made. The hot steel raises the temperature of the inner surface of the mold, setting up surface compression which exceeds the elastic limit of the material. Plastic flow occurs, localizing in all regions of weakness. Then when the mold cools, the compression changes to a tension which also exceeds the elastic limit, and cracks develop. As a result, the mold is eventually scrapped.

Fig. 1 shows a mold which was scrapped because the thermal cycle outlined developed cracks to the limit of practical use. Fig. 2 shows the effect on the surface of the ingot of mold conditions similar to those shown in Fig. 1.

The optimum cross-sectional shape of the ingot mold is a compromise between that most desirable for the mold itself and that which is best for the ingot.

PLASTICITY IN THE INTERIOR OF STEEL INGOTS

The entire cycle of the freezing, cooling, reheating, and rolling of an ingot is full of problems in plasticity. Plastic phenomena are factors in the formation of primary and secondary pipes, internal stresses, internal cracks, and other imperfections.

Much is supposed to be known about plastic trends and tendencies as they influence the freezing of steel ingots, and probably some of this supposed knowledge is correct. But it is all vaguely qualitative. The engineer demands definite quantitative information from the plastician.

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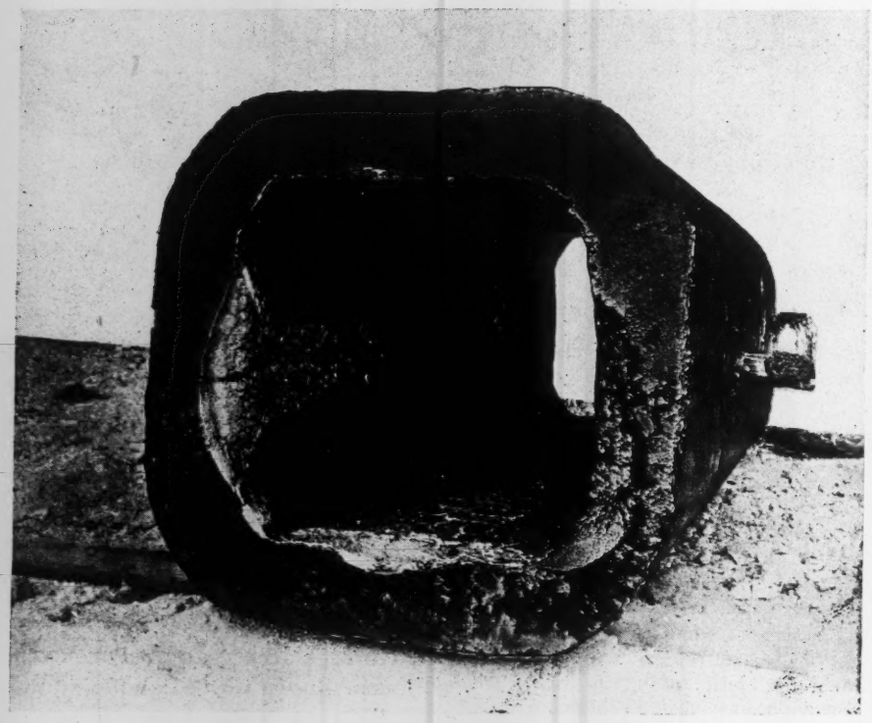

FIG. 1 A SCRAPPED INGOT MOLD

PLASTICITY IN STEEL BLOOMS

After an ingot has been rolled into a rough bloom, it is necessary, for all quality production, to remove the surface imperfections from the bloom by some mechanical means. This is accepted as a fundamental necessity by the industry. The process requires valuable time, costs money, and wastes steel. After the mechanical improvement of the surface is completed, additional improvement is often considered necessary, in the shape of heating the bloom in an oxidizing atmosphere for further rolling. In some branches of the industry this alone destroys as much as 2 per cent of the steel.

The mind of the author utterly revolts at the acceptance of the removal of any of the surface of steel blooms as a fundamental necessity. The attack on the conditions now demanding this drastic treatment must start at least as far back as the ingot, and there is an important rôle in the attack for the plastician to play.

Fig. 3 shows two blooms that were chipped down more than an inch below the surface without reaching the bottom of longitudinal cracks. Some ten thousand pounds of steel had to be scrapped because these blooms did not possess the plastic characteristics necessary to resist the existing conditions. Fig. 4 shows a pile of blooms in which no deep local chipping was necessary, and yet a regrettable amount of steel was lost at the expense of time and money.

In attacking the problem of eliminating chipping, the plastician can first define the plastic flow which occurs under present ingot and rolling practice. Then he can show the improved condition which will exist with an ingot of a new shape. And finally, he can develop the ideal shape of rolls for the blooming mill.

Here the plastician must be warned of a profound conviction which he will encounter as soon as he starts to dabble with the cut of rolls. The roll designer in the steel industry today has become so thoroughly saturated with the performance of steel during the act of rolling, that he knows intuitively what the steel wants to do and what it will stubbornly refuse to do. The roll designer is sincerely convinced that nothing but long practical experience with the actual rolling of steel can ever fit a man to design roll passes. Up to the present, the attempts of pure theorists to improve on the procedure of the practical roll designer have sustained this conviction. While we are optimistic that the plastician who enters the steel mill in the way outlined later in this paper, can eventually advance the art of rolling steel, we strongly recommend that he go about his task in the spirit of humility, and with his mind fortified against the discouraging failures that in all probability will attend his early efforts.

CREEP

The outstanding opportunity for the plastician to render immediate service to the steel industry is in connection with the phenomenon of creep under stress and at elevated temperature. The subject is now highly controversial, there being no agreement as to either the mechanism of creep or the proper methods for the evaluation of resistance to creep. And finally, only by cut and try and inference can the industry build higher creep resistance into new steels.

It may appear inconsistent to insist, as is done later in this paper, that it is necessary for the plastician to grind through a long apprenticeship in the making and handling of steel before he plunges into the analysis of plastic problems, and then in the next breath demand that he undertake a highly theoretical investigation of the mechanism of creep. The inconsistency is, however, more apparent than real. The plastician is advised to build for himself a sound foundation on the twin pillars of practise and theory. From this base he can launch effective attacks on the specific creep problems which are brought to him for solution.

The taking of a firm stand on the general method and detailed procedure for the experimental determination of creep stress is a sure way to start an argument. The stand outlined here is limited strictly to seamless steel tubes in service similar to applications in the petroleum refining industry. In this service, the tube is subjected to internal pressure by a hot medium that is chemically more or less hostile to it, and the outer surface of the tube is surrounded by atmosphere varying all the way from air to hot gases.

The author's position on creep testing within the specified limits is based entirely on his analysis of the work of other investigators. He has abstained from this line of testing until a basis of procedure can be developed which satisfies certain prime fundamentals that are largely neglected in all the work which he has studied. These fundamentals are:

(1) The test piece must include the entire 360 degrees of a service tube.

(2) The type of stress imposed by the test must coincide with service stress.

(3) The tests must be conducted not only on sections of tubes in the "as-shipped" condition, but also, and far more

important, on sections of tubes removed from service after a wide range of predetermined lengths of time on stream.

(4) The tests must make independent determinations of the creep stress of materials located in three different portions of the cross-section of the tube: (*a*) material adjacent to the inner surface of the tube, (*b*) material adjacent to the outer surface of the tube, and (*c*) material remote from both the inner and outer surfaces of the tube.

(5) The tests must be of short duration.

This conception of creep testing is heretical, but the unescapable logic of these fundamentals places the burden of proof on the shoulders of the advocate of the standard long-time tension test as it has been conducted on tubular materials destined for refinery service.

It has been definitely proved that the atmosphere surrounding the test piece produces a profound effect on the creep stress. At one stroke, this fact destroys the sure applicability of all creep tests conducted in atmospheric air and on materials destined for service under more hostile conditions.

FIG. 2 AN INGOT FROM A HEAT-CHECKED MOLD

If further condemnation of long-time creep testing is required, it is found in the history of one of the most elaborate long-time test programs carried out in this country, where one entire class of material on which work was done became almost obsolete for the service involved before the program was completed.

The author's mind is definitely set on the fundamental necessity of leaving the long-time test to actual service, because of the impossibility of duplicating or even approximating service conditions in the laboratory. The function of the creep test then becomes the close approximation of the original characteristics of the material, followed by a closely approximate evaluation of any deterioration inflicted upon the material by its hostile service environment.

Until the contrary is established beyond all possibility of doubt, the author is proceeding on the assumption that, in the service in which he is interested, there is no such thing as an enduring and fundamental creep characteristic. There is too much chance of an insidious, progressive, service deterioration to permit the assumption that creep or any other characteristic of tube material is of a fundamental and enduring nature. Following this doctrine, in the investigation of characteristics other than creep, a considerable range of characteristics has been removed from the doubtful class, for various tube materials and services, while for other materials there are certain very important characteristics which suffer deterioration. In view of these accepted facts, the only sensible course is to consider the creep characteristic as a drooping variable in service until the contrary has been thoroughly proved.

The author refuses to consider creep tests or any other tests conducted on strips cut parallel to the axis of a seamless-steel tube as representing a true transverse characteristic for any given material, until the reliability of the axial test has been definitely proved for that particular material.

Reference has been made to the duty of the plastician in connection with the analysis of the mechanism of creep. This duty is rendered of instant importance by the extensive plans now under way for the organization of cooperative research on the creep characteristic of seamless-steel tubular products. The plastician can assist in the determination of the fundamental basis on which the test equipment is selected. He can also parallel the test work of the program with a study of the mechanism of creep.

The study of this mechanism carries us immediately into the field of rheology, and here help is needed. We demand in no uncertain terms the best assistance the rheologist can give in throwing more light of a fundamental nature on this vital subject. The analytic plastician is the logical interpreter to bridge the gap between the rheologist on the one hand and the metallurgical and mechanical engineer on the other.

HOW TO START THE ANALYSIS OF STEEL PLASTICITY

The plastician who plunges prematurely into the mathematical analysis of steel plasticity without a laborious preparation of background is doomed in advance to discredit his art. Having made up his mind to attack the plastic analysis of steel, his first move should be the formation of an alliance with forward-looking steel men who are willing to pilot him through enough of the literature to bring him pretty well up to date on steel-mill practise. He will spend enough time in the steel mill to become intimately familiar with the entire practise as it applies to ingots and blooms, etc. If he is wise, he will reserve the right to doubt the fundamental truth of everything that he hears or reads, but he will keep these doubts to himself until he is sure of his ground.

This apprenticeship requires time and patience, but after it has been completed faithfully, the plastician will find that he has laid a sound foundation for the analysis not only of ingot plasticity, but of the whole subject of steel plasticity. And finally, throughout his entire activity he will work hand and

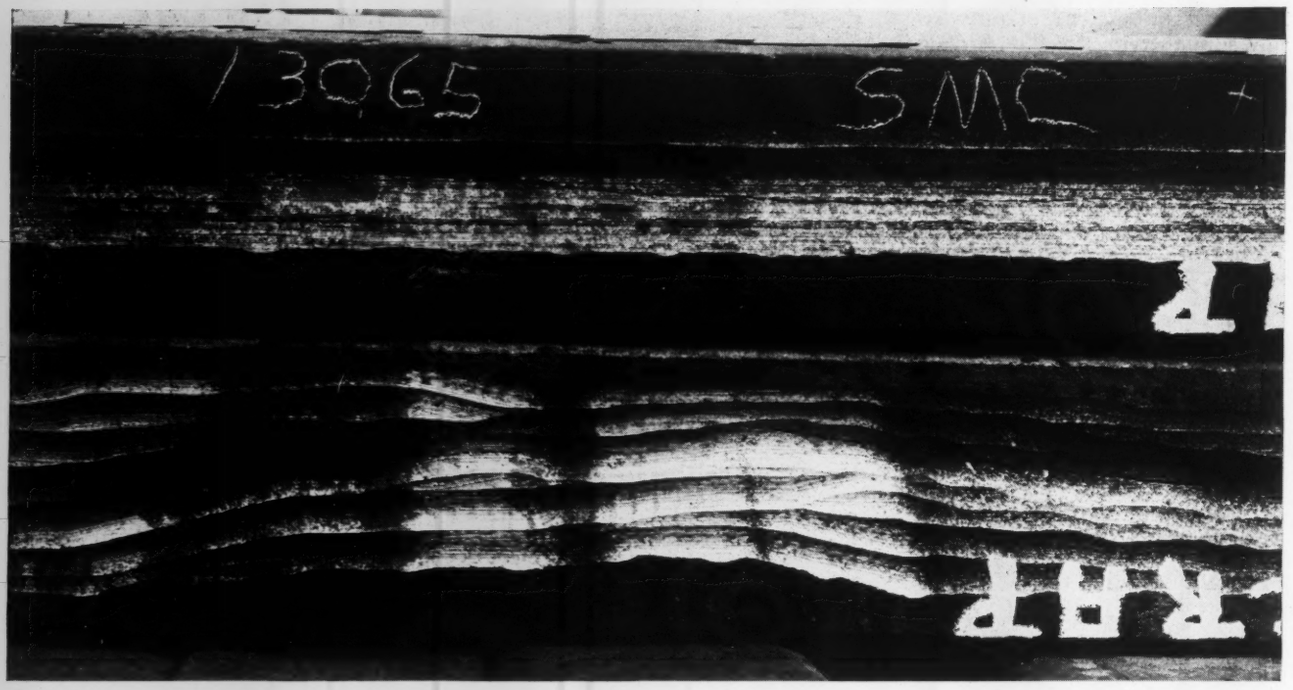

FIG. 3 BLOOMS SCRAPPED BECAUSE OF CRACKS

glove with the men who have brought the steel industry to its present state of efficiency.

The plastician who plans to attack any phase of steel plasticity cannot be urged too strongly to start with the ingot on the one hand and with the atom on the other hand. Unless he does this, he will be in continual danger of overlooking ingot conditions which have persisted in the ultimate product.

CONCLUSION

When the Plasticity Committee of The American Society of Mechanical Engineers laid on the writer the duty of preparing this paper, they requested him to bring out all the opportunities for the plastician throughout the production of seamless steel tubes. Only a few of the outstanding plasticity problems have been dealt with briefly. But in order to convince the plastician that a lifetime of strenuous analysis awaits him in any line of steel production, a classification of some of the variables which are recognized as demanding consideration in the making of seamless-steel tubes has been prepared, as has also a list prepared by a steel mill covering some of the variables which in this mill are regarded as important in the making of steel for seamless tubes.[2]

The major purpose of this paper is to root firmly in the mind of the plastician the conviction that the only way that he can build for himself an authoritative position on problems of steel plasticity is to work within the steel industry, starting at the beginning of his problem, and following the plastic trail from that beginning to the end.

[2] These lists have been omitted from this abridged form of Mr. Eaton's paper.—Editor.

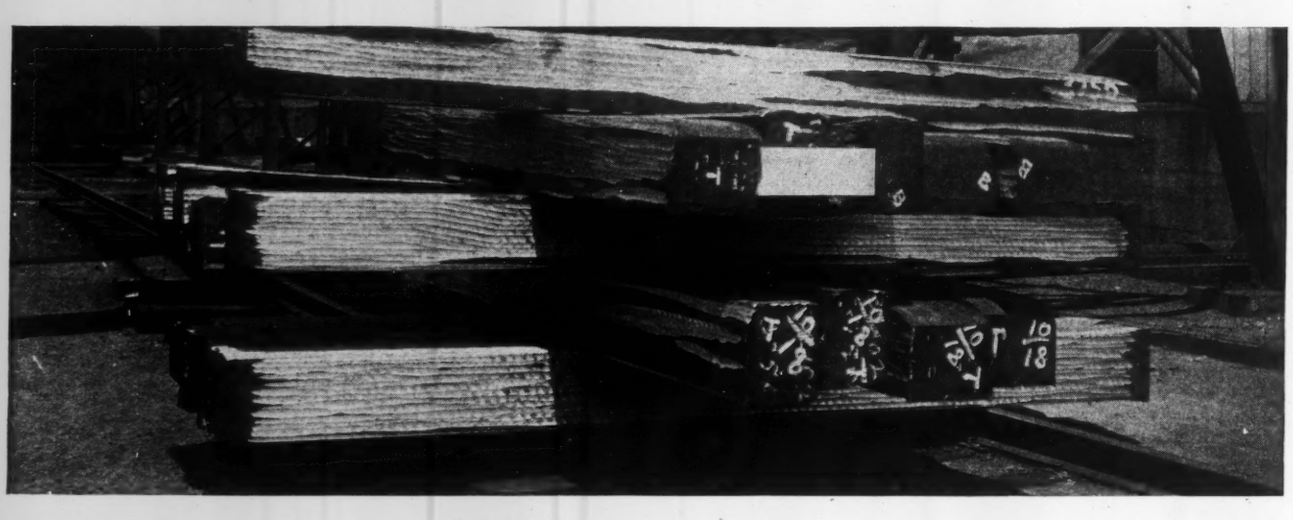

FIG. 4 A PILE OF CHIPPED BLOOMS

LOGIC *of* OILINESS

By MAYO D. HERSEY[1]

This paper undertakes to clarify the definition of oiliness and the purposes to be served by research on oiliness. A distinction is made between the general concept of oiliness and scientific definitions adequate for the laboratory measurement of oiliness. A further distinction is made between oiliness, which is purely a friction-reducing property, and properties governing wear and seizure. The status of thin-film lubrication theory is indicated. Different hypotheses as to the cause of oiliness are mentioned. The requirements of a satisfactory oiliness machine and possible methods for establishing a numerical scale of oiliness are considered. If such numerical values can be obtained, they should be correlated experimentally with the friction of machine elements, including bearings, gears, and cutting tools.

A WIDESPREAD interest in the subject of oiliness has become evident on the part of engineers and chemists within the past few years. This may be accounted for by (1) the efforts of The American Society of Mechanical Engineers[2] and European investigators[3] in promoting scientific research on oiliness; (2) competitive commercial production of lubricants containing small additions of fatty acid or other friction-reducing ingredients;[4] and (3) gradual recognition of the importance of reducing frictional resistance in industrial and other machinery by every means possible, based on practical experience in the operation of gears, cutting tools, and roll-neck and other types of bearings under heavy load conditions.[5]

While this more evident interest in the subject is a contemporary phenomenon, the general concept of oiliness as a friction-reducing property separate from ordinary viscosity dates back at least to the pioneer work of Albert Kingsbury.[6,7] Selective adsorption and other possible contributing factors of oiliness were discussed in the first published report of the A.S.M.E. Special Research Committee on Lubrication,[8] and had already been brought to the attention of the committee by Mr. Kingsbury at its first meeting,[9] in 1915.

In the experiments on the friction of screws,[6] mineral oil, lard oil, and mineral oil containing graphite were compared on both ferrous and non-ferrous metals under loads up to 14,000 lb per sq in., and in the work reported on the new oil-testing machine,[7] lard oil and mineral oils were compared on brass blocks with a steel spindle under loads of the order of 2500 lb per sq in., which were found preferable to heavier loads. Subsequent experiments by many investigators have confirmed the superiority of fatty over mineral oils for low-speed, heavy-load lubrication. Any attempt to summarize these numerous experiments, or to describe the various testing machines, will be considered outside the scope of the present paper. The net impression that any one must derive from the recent literature is a realization of the need for clarifying the definitions and objectives underlying oiliness research before going on to accumulate more data.

The general concept of oiliness can hardly be presented more clearly today than it was some thirty years ago by Kingsbury in the second of the two papers cited:[7]

> It has become well recognized by experimenters that there are two important properties of lubricating oils and greases on which their value depends.... Viscosity is the property by virtue of which the lubricants form comparatively thick films between the rubbing surfaces, permitting perfect lubrication.... A condition essential to the formation of such films, as shown by Reynolds, is that the rubbing surfaces should have a very slight inclination to each other in the direction of their relative motion.... When the loads are very great or the surfaces irregular, or when the conditions are otherwise such as to make the necessary inclination impossible, it is well known that the action of the lubricant is imperfect.... Under any of these circumstances the effect of the lubricant in reducing friction depends mainly upon the "body"[10] or "oiliness." The nature of this property, or combination of properties, is not well understood, but it appears probable that it is an intensified viscosity in that part of the fluid within the region of the attraction of the surface molecules of the metal.

The late Dr. R. H. Thurston, in his published discussion of the foregoing paper,[7] stated:

> Professor Kingsbury's oil-testing machine....seems especially suited to such peculiarly fine work of investigation as is here illustrated.... It brings out, as never was done before, the differences between "viscosity" and what its inventor calls "body" [oiliness], a quality which remains to be defined.

SCIENTIFIC DEFINITIONS OF OILINESS

The scientific or technical definition of a new physical quantity may differ considerably from its dictionary definition, or from the language used in picturing the general concept involved. It should be so expressed, if possible, as to separate the new quantity from previously recognized quantities and

[1] Research and Development Laboratories, Socony-Vacuum Corporation, Paulsboro, N. J. Mem. A.S.M.E.

[2] A. E. Flowers and M. D. Hersey, "Contributions apporteés par l'American Society of Mechanical Engineers à l'étude du graissage." Compte-rendu, Congrès du Graissage, Strasbourg, 1931, pp. 419–434. "Lubrication Research of The American Society of Mechanical Engineers," MECHANICAL ENGINEERING, vol. 54 (1932), pp. 269–270.

[3] Investigations by Hardy, Woog, Vieweg, Voitländer, and others on oiliness are summarized by S. Kiesskalt, Das Gleitlager im letzten Jahrfünft, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 75 (1931), pp. 1025–1026.

[4] See, for example, H. M. Wells and J. E. Southcombe, "The Theory and Practice of Lubrication—the Germ Process," *Jour. Soc. Chem. Ind.*, vol. 39 (1920), pp. 51–60 (T); J. E. Southcombe, "Some Contributions to the Theory and Practice of Lubrication," Trans. N. E. Coast Inst. Engrs. and Shipbuilders, vol. 44 (1928), pp. 207–228.

[5] See, for example, W. C. Wilharm, "The Rôle of Oiliness in Industrial Lubrication," *Ind. & Eng. Chem.*, vol. 18 (1926), pp. 463–467.

[6] A. Kingsbury, "Experiments on the Friction of Screws," Trans. A.S.M.E., vol. 17 (1895–1896), pp. 96–116.

[7] A. Kingsbury, "A New Oil Testing Machine and Some of Its Results," Trans. A.S.M.E., vol. 24 (1903), pp. 143–160.

[8] "Report of Subcommittee on Lubrication," MECHANICAL ENGINEERING, vol. 41 (1919), p. 537.

[9] Minutes of the meeting of the A.S.M.E. Research Subcommittee on Lubrication, Dec. 8, 1915.

[10] The term "body" was carefully used by Kingsbury as a synonym for oiliness, but can no longer safely be used as an exact scientific term.

should contain, implicitly at least, the essential principles required for a laboratory measurement of the quantity.

Herschel,[11] in his studies of lubricating oil, was impressed by the need for a strict definition of oiliness and states:

> With incomplete film lubrication, the differences in friction with different lubricants under otherwise identical conditions cannot be accounted for by differences in viscosity. Therefore it is necessary to consider some other property or properties of the lubricant. This property is only vaguely understood; it is not identified with any recognized physical or chemical constants and is known by a variety of names such as body, oiliness, greasiness and the like. I shall use the word oiliness and define it as the property that causes a difference in the friction when two lubricants of the same viscosity at the temperature of the film are used under identical conditions.

An alternative statement which the writer advocated some years ago would define oiliness as that property which can make a difference in the friction when two lubricants, having the same viscosity at the temperature *and pressure* of the film, are used under identical conditions. Reference is made to the effective fluid pressure in the film, whether produced by the steady application of a heavy external load, or by the momentary tangential approach of high spots on roughened surfaces in relative motion.

Suppose two mineral oils *A* and *B* have the same viscosity at the temperature of the film and atmospheric pressure, while at the same temperature, but at the true pressure in the film, oil *B* has the greater viscosity. Suppose, further, that the frictional resistance is found to be less with oil *B* than with oil *A*. Then on the basis of Herschel's definition, the situation is simply enough described by saying that oil *B* has the greater oiliness, and the phenomenon of increased viscosity due to high hydrostatic pressure is admitted as a contributing factor of oiliness. But if the alternative definition is adopted, it can only be said that these particular oils are ineligible for comparison.

Both definitions demand that the lubricants to be compared shall have the same viscosity under some specified condition. Herschel's definition implies that the viscosities need only be identical at atmospheric pressure. The alternative definition, in its effort to completely disentangle oiliness from viscosity, specifies that the viscosities shall be identical at the true film pressure, a requirement that cannot easily be met, since in general the effective pressure in the film is unknown.

Upon reflection it will be realized that an analogous difficulty is involved in determining the true film temperature. In practise, this is usually taken equal to the temperature of the bearing surfaces, which in turn may be interpreted either as the mean temperature or the temperature at a selected point. It is suggested that the latter be designated as the test temperature and substituted for the words "temperature of the film." With this modification, Herschel's definition might be stated: "Oiliness is that which may cause a difference in the friction between two tests under identical conditions, in which the lubricant has the same viscosity at the test temperature and atmospheric pressure."

A new point of view has been suggested by Dr. W. F. G. Swann[12] in a recent conversation. Instead of attempting to define oiliness a priori, this might be postponed until empirical equations are available for the friction of machine elements, showing very completely how the frictional resistance is related to all of the physical and geometrical variables that can be changed while the tests are restricted to one particular combination of lubricant and bearing metals. Such an equation must involve a set of numerical coefficients, or empirical constants, which will be found to have different values when the tests are repeated with different materials. One or more of these constants may be identified with the viscosity of the lubricant. The remaining constants constitute the group of properties known as oiliness. It was pointed out by Dr. Swann that the foregoing represents the procedure usually followed throughout the history of physics in defining new properties of materials. Electrical resistivity, Young's modulus of elasticity, and viscosity may be cited as concrete examples, all of these, however, involving only the most simple mathematical relations between the directly observed variables.

Very possibly this empirical-equation procedure may prove to be the ultimate solution of the oiliness problem. An interesting step in that direction was taken by Kingsbury in his use of the rotating tapered plug for exploring the relation between friction, film thickness, and speed over a wide range of the variables.[8]

In the meantime, the lubricants manufacturing industry and users of lubricants are endeavoring to develop relatively simple laboratory tests by which more immediate results may be secured. For this purpose, the Herschel definition is generally accepted as representing the practical engineering point of view, even though it may not wholly dissociate oiliness from viscosity in a physical sense.

The suggestion has been offered by Dr. R. Bulkley for future consideration that oiliness might be defined as the reduction in friction obtained by the use of a given lubricant under boundary-lubrication conditions, compared with the friction of the unlubricated surfaces. It would remain to define boundary conditions more precisely, but in general they are understood to be conditions under which friction is unaffected by viscosity.

PROCEDURE FOR COMPARING LUBRICANTS OF UNEQUAL VISCOSITY

Accepting Herschel's definition for the time being at least, the investigator is next confronted with the question how to compare the oiliness of two lubricants of unequal viscosity. It may at once be granted that this is not always necessary. For many commercial purposes, the object of the test is to determine the effect of adding such small percentages of different ingredients that the viscosity of the original oil is not materially changed.

Various plans for comparing oils of unequal viscosities have been considered. Most familiar of all is the static-friction procedure adopted by Hardy[13] and others in England. This procedure is supported by the fact that viscosity must become inoperative at zero speed. If, however, it should be found experimentally that two lubricants of identical viscosity and having the same oiliness under the static interpretation could differ in kinetic friction, it would seem necessary to attribute such difference to some further property other than viscosity and oiliness.

Another familiar expedient consists in equalizing the viscosities of the two oils by a change of temperature. This involves the assumption that oiliness is independent of temperature.

A third procedure[14] consists in comparing the two oils at equal values of the generalized variable G, denoting ZN/P.

[11] W. H. Herschel, "Viscosity and Friction," Trans. S.A.E., vol. 17, pt. 1 (1922), pp. 282–320.

[12] Director, Bartol Research Foundation of the Franklin Institute, Swarthmore, Pa.

[13] W. B. Hardy and J. K. Hardy, "Note on Static Friction and on the Lubricating Properties of Certain Chemical Substances," *Phil. Mag.*, vol. 38 (1919), pp. 32–48. W. B. Hardy, "Boundary Conditions in Lubrication," Dict. Applied Physics, Glazebrook, vol. 1 (1922), pp. 572–579 (Macmillan).

[14] M. D. Hersey, *Jour. Am. Soc. Naval Engrs.*, vol. 35 (1923), pp. 648–674 (Fig. 14).

In this expression, Z is the viscosity at atmospheric pressure but at the temperature of the test, N the speed in revolutions per unit time, and P the load per unit of some designated area. It is understood that the test surfaces are maintained constant, a condition more easily met by varying the speed than by varying the load. Thus, for example, if oil B has three times the viscosity of oil C, the friction test might be conducted at one-third of the speed. This procedure is supported by the conclusion[15] that if no other property of the lubricant than its ordinary viscosity Z were responsible for the friction observed, any two lubricants must give the same coefficient of friction f at the same value of G. Differences in friction are proof that other properties than the viscosity Z are entering in, to which the name oiliness may be collectively given as a matter of definition.

Obviously, if the load is held constant, the same conclusions will be reached by plotting f against ZN instead of against G. A more open scale may be obtained from the reciprocal diagram, in which f is plotted against $1/ZN$ or $1/G$.

In all three cases, the actual friction measurements are made at equal values of G; even in following the static procedure G has the same value for both lubricants, namely zero.

RELATION OF OILINESS TO THE BEARING METALS

As emphasized by Herschel and others,[16] oiliness is to be regarded as a joint property of the lubricant and metal; or, to be more exact, of the lubricant and the materials forming the two bearing surfaces. Other examples of joint properties in physics are mutual inductance and thermoelectric power. Thus, whenever oiliness is referred to as a property of the lubricant alone, as in the original phraseology of Herschel's definition, constancy of bearing material is understood. The modified definition, in which reference is no longer made to *two* lubricants, contemplates more explicitly the comparison of different bearing metals with the same lubricant.

Woog[17] classes oiliness as a latent or potential property of the lubricant rather than as an ordinary fixed property of materials, since it is induced or brought into action only by proximity of the lubricant to a solid surface.

In identifying the system whose oiliness is to be measured in any given test, it may be found necessary to specify the roughness of the bearing surfaces in a geometrical sense, as well as to identify the bearing materials physically and chemically.

Oiliness is referred to in the foregoing paragraphs and elsewhere as a single property merely for simplicity of language, without meaning to imply any departure from the more technical concept of oiliness as a collection or group of properties.

RELATION OF OILINESS TO WEAR AND SEIZURE

The only scientific definitions proposed for oiliness are based upon the historical concept of oiliness as a friction-reducing property. There is no warrant for assuming a priori that the lubricant of superior oiliness will be superior to others in reducing wear or in preventing seizure.

It does not appear that the terms "wear" and "seizure" have yet been scientifically defined, or that the elementary physical factors entering into the phenomena have been systematically investigated, although extensive data have been obtained on the metallurgical factors.[18]

Thus the problems of wear and seizure remain for the future, and if any correlation between oiliness and wear or seizure phenomena exists, it must be discovered experimentally. All that can be said in advance is that (1) other things being the same, a lubricant of superior oiliness will develop less temperature rise, and to that extent conditions will be more favorable for reducing wear and preventing seizure; and (2) the oiliness problem should be attacked first, in order that lubricants of equal oiliness as well as equal viscosity may be selected for reference in wear and seizure investigations.

THEORY OF THIN-FILM LUBRICATION

Thick-film lubrication, already dealt with satisfactorily by mathematical methods, lies at one end of the lubrication spectrum; wear and seizure at the other extreme. Thin-film phenomena associated with oiliness may be pictured as occupying the middle interval.

This interval of thin-film lubrication may be further subdivided into two somewhat overlapping ranges characterized by bulk phenomena and boundary lubrication,[13] respectively. Although oiliness may be commonly thought of as associated with boundary lubrication, it will be recalled that there is nothing in the definition of oiliness excluding bulk properties as such.

Only one bulk property, the ordinary viscosity Z at atmospheric pressure, has been excluded from oiliness by definition. Two such properties that may be expected to have considerable influence on oiliness are the temperature and pressure coefficients of viscosity, $(1/\mu)\,\partial\mu/\partial t$ and $(1/\mu)\,\partial\mu/\partial p$, respectively, in which μ denotes the viscosity as a function of temperature t and pressure p. The symbol Z has been reserved for the value of μ at the test temperature and atmospheric pressure. Other bulk properties to consider are the heat capacity of the lubricant per unit volume and its thermal conductivity. The elastic constants of the metals are also of primary importance.

In the overlapping region where boundary friction is a contributing but not the predominating factor, it might be represented to a first approximation by the static coefficient f_0.

The picture of oiliness represented by the foregoing collection of properties is perhaps too simple to be useful, but, if so, it is capable of modification step by step in accordance with each new item of experimental evidence. Constructive theoretical formulation of the implied relations should be possible except as limited by the mathematical labor involved.

A start might be made as in the classical theory of Reynolds by neglecting velocity components perpendicular to the direction of motion of the bearing surfaces, and by treating an ideally simplified cross-section, or profile, of the bearing surfaces. The essential difference is that in dealing with thin-film lubrication, these surfaces can no longer be assumed perfectly smooth and rigid. Roughness of profile might be approximated by sine curves, triangular notches, and the like. In some such manner, it might be possible to calculate the change in contact area with load, also the local temperatures and pressures generated by the tangential approach of high spots on the opposite rubbing surfaces; and finally to obtain the total friction by integration.

The evident mathematical difficulties are such as to direct attention to the method of dimensions, by means of which the familiar ZN/P relations were derived for the case of thick-film lubrication.[15] Accordingly, in a recent paper, the dimensional method has been extended to some of the simpler conditions of thin-film lubrication.[19] The result of this analysis is to reduce

[15] *Jour. Wash. Acad. Sci.*, vol. 4 (1914), pp. 542–552; Trans. A.S.M.E., vol. 37 (1915), pp. 167–202.

[16] American Instrument Co., Inc., Bull. 112, Washington, D. C., 1929, 4 pp.; *Am. Machinist*, vol. 70 (1929), pp. 919–921 and 975–977.

[17] P. Woog, "Contribution à l'étude du graissage. Onctuosité. Influences moléculaires," Paris, Delagrave, 1926, 277 pp.

[18] L. Jordan, "The Wear of Metals," MECHANICAL ENGINEERING, vol. 53 (1931), pp. 644–650.

[19] "Thin-Film Lubrication of Journal Bearings," *Jour. Wash. Acad. Sci.*, vol. 23, June 15, 1933, pp. 297–305.

the number of independent variables to a minimum, thus correspondingly simplifying the experimental work to follow.

HYPOTHESES TO ACCOUNT FOR OILINESS

At least six hypotheses have been offered in the endeavor to explain the causes of oiliness.

(1) *Plasticity*. Archbutt and Deeley,[20] in 1900, attributed oiliness to the thickness of the residual film, which they pointed out might be due to plasticity.[21]

(2) *Intensified Viscosity*. Kingsbury[7] found, in 1902, that any increase in viscosity would be accompanied by a reduction in friction under conditions where oiliness is effective, and suggested that such an increase might be caused by the attractive force of the metal molecules.

(3) *Secondary Bulk Effects*. Changes in viscosity due to high pressures and temperatures produced locally within the film were mentioned by Kingsbury[9] in 1915 as contributing factors of oiliness, and investigated by the Special Research Committee on Lubrication.[8,19]

(4) *Adsorption*. Selective adsorption was suggested by Kingsbury,[9] in 1915, to explain the oiliness of lard and sperm oils and cutting mixtures, and discussed by the A.S.M.E. committee in its first published report.[8] Adsorption was further investigated and applied to lubrication by Langmuir,[22] to whom is due the monomolecular concept; as well as by Hardy,[13,23] Woog,[17] and others.

(5) *Adhesion*. Some investigators have assumed that oiliness depends on the degree of adhesion of the lubricant to the metal.[24] Efforts have been made to measure the amount of oil adhering under centrifugal force.[25] It has been suggested that some connection must exist between oiliness and capillarity.[20,26] Recent experiments, however, indicate that the relations involved are not as simple as usually supposed.[27]

(6) *Stratification*. X-ray observations have been interpreted as revealing that the orientation and stratification of the lubricant molecules extend to a considerable distance from the metal surface. Woog[17] and Trillat[28] have assumed that slip surfaces are formed between successive layers of molecules;[29] and that therefore such stratification is a contributing factor of oiliness.

Any of the six hypotheses may be combined with one or more of the remaining five, with the hydrodynamic theory of lubrication, or with the chemical reaction theory of extreme-pressure lubricants.[30] Although the chemical theory has been suggested as an oiliness hypothesis, it has not been included in the list, since the mere fact that new materials are formed, differing in viscosity or oiliness from those originally present, hardly constitutes an explanation of oiliness.

The possibility of a selective action under hypotheses nos. 2, 4, or 6 might be combined with secondary bulk effects. The significant pressure and temperature coefficients of viscosity would then be those of the selected ingredient, rather than of the original lubricant.

The number of combinations of six hypotheses taken from one up to six at a time is so great that for this reason alone some time must elapse before the true explanation of oiliness can be demonstrated. A more immediate purpose to be served by the foregoing list is to aid in scrutinizing each proposed method of test so that differences of oiliness will not escape detection during the laboratory tests, only to arise later under service conditions.

REQUIREMENTS OF A SATISFACTORY OILINESS TEST

Oiliness tests are absolute or relative. An absolute test is one in which the observations are confined to a single lubricant and set of bearing metals; the empirical-equation method would be an example.

Relative tests are those in which the lubricant under test is compared with others. In such a test, one or more of the lubricants plays the part of a material standard of oiliness. Oiliness machines as ordinarily built are intended for relative tests only.

In considering the fundamental requirements of an oiliness test, it is of interest to keep in mind the diversity of bearing surfaces represented in the existing oiliness machines. These include, to mention only kinetic oiliness machines, (1) ordinary journal bearings; (2) two types of machine with continuous parallel surfaces; (3) at least four types with discontinuous or separated parallel surfaces; and (4) five or six types with tangent surfaces—in all, a dozen or more geometrically different types of bearing surface.

It is apparent that the inventors did not feel restricted to the types of bearing surface occurring in practise. This gives rise to the question, how are the results to be interpreted and practically applied? The answer would seem to be that an empirical correlation must be worked out and represented by curves which will then be available for future reference. It will be seen that the fundamental requirements to be met may be incompatible with the use of practical bearing surfaces in oiliness tests.

The foremost requirement is that oiliness tests shall be based upon actual friction measurements. This is evident from the definition and need only be emphasized here because it is so often overlooked. It is immaterial in principle whether the friction be measured mechanically or thermally.

A second requirement is reasonable freedom from wear and seizure effects, and in general, a minimum expenditure of energy otherwise than in overcoming frictional resistance. While

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[20] L. Archbutt and R. M. Deeley, "Lubricants and Lubrication," London, Griffin, 1900, 451 pp.

[21] Although the clogging of capillaries was put forward a few years ago (R. E. Wilson and D. P. Barnard, 4th, *Ind. & Eng. Chem.*, vol. 14 (1922), pp. 683–694) as evidence for plastic adsorbed films of relatively great thickness, more recent experiments have shown that the clogging disappears when the filtering is improved, and that such films must be less than one-millionth of an inch thick (R. Bulkley, Bureau of Stands. *Journal of Research*, vol. 6 (1931), pp. 89–112; RP 264).

[22] I. Langmuir, "The Mechanism of the Surface Phenomena of Flotation," Trans. Faraday Society, vol. 15, pt. 3 (1919–20), pp. 62–74.

[23] W. Hardy and M. Nottage, "Adsorption. A Study of Availability and Accessibility," Proc. Roy. Soc. A, vol. 138 (1932), pp. 259–283.

[24] Adhesion was discussed briefly in the 1919 Committee report cited, and at greater length by E. C. Bingham, "Cutting Fluids," Bureau of Standards Technical Papers No. 204, vol. 16 (1921), pp. 35–76, with references to the earlier literature.

[25] See, for example, A. Boutaric and R. Amiot, "Recherches expérimentales sur l'adhérence aux metaux des couches lubrifiantes," *Comptes Rendus*, vol. 193 (1931), pp. 593–594; *Ann. d. Combustibles Liquides*, 1931, pp. 443–458.

[26] A. A. Adler, Trans. A.S.M.E., PME-53-4, 1931, p. 30.

[27] R. Bulkley and G. H. S. Snyder, "Spreading of Liquids on Solid Surfaces. The anomalous behavior of fatty oils and fatty acids with experiments leading to a tentative explanation." *Jour. Am. Chem. Soc.*, vol. 55 (1933), pp. 194–208; *Nature*, vol. 131 (1933), pp. 407–408.

[28] J.-J. Trillat, "Les théories modernes sur la lubrification." *Science et Industrie*, No. 158 (1927), 7 pp. "Moderne Anschauungen über die Reibung," *Metalwirtschaft*, vol. 7 (1928), pp. 101–108. "L'étude de la constitution des huiles, des graisses, et des lubrifiants au moyen des rayons X," *Rev. Scientifique*, vol. 68 (1930), pp. 718–725.

[29] Kingsbury's experiments (MECHANICAL ENGINEERING, vol. 41 (1919), p. 537) showed no evidence of slip up to rates of shear as high as 261,000 radians per second and with films as thin as one-forty-thousandth of an inch, these limits corresponding to fairly high tangential stresses.

[30] H. C. Mougey and J. O. Almen, "Extreme-Pressure Lubricants," Bull. A.P.I., Refining Div., Dec., 1931, pp. 76–94. As the problem of extreme-pressure lubricants is primarily one of load capacity rather than friction, it should not be confused with the oiliness problem.

complete freedom from wear is ideally desirable, a compromise may be called for to avoid conflict with other requirements.

A third requirement is that the friction shall be influenced to a minimum extent by the viscosity of the sample, as measured at the test temperature and atmospheric pressure. This necessitates either (1) a heavy load combined with low speed, or (2) a special design of the bearing surfaces to prevent hydrodynamic film formation; or both. Here, then, is one of the reasons for making the bearing surfaces of an oiliness machine different from those found in practical machinery.

A fourth requirement is that of the variability of physical conditions over the full range to be met in service, in so far as oiliness may depend on such conditions. This requirement offers little difficulty if it is permissible, following Sir William Hardy, to focus our attention wholly on static friction. For the present, it would be safer to assume that oiliness may depend on any or all of the operating variables such as speed and load. The possibility of irreversible effects, depending on the rates of change of the variables and on the precise order of sequence of every step in the procedure, should also not be overlooked. Such irreversibility will generally be made evident by a hysteresis loop on the coefficient-of-friction diagram. As already noted, reference to the different oiliness hypotheses may be of aid in deciding what conditions ought to be included in the oiliness test.

A fifth requirement, reproducibility of results, an obvious enough requirement in all technical measurements, has been found notoriously difficult of attainment throughout the history of oiliness research. The solution appears to lie in a closer adherence to Kingsbury's procedure of 1902, in accordance with which all comparisons of lubricants are to be completed before disturbing any of the mechanical adjustments.[7] Under this procedure, more reliance is placed on the material standards of oiliness, and less on the constancy of mechanical conditions.

A final requirement is that the material standards of oiliness shall be satisfactory. This involves the usual requirements of any material standard, such as permanence and reproducibility. It also requires convenient spacing or distribution of standards over the entire viscosity and oiliness range, so that it will not become necessary to compare a new lubricant with one of widely contrasting viscosity or oiliness.

In addition to oiliness tests based upon friction measurements, which are the only oiliness tests properly so called, numerous indirect tests for oiliness have been proposed. These are based upon other phenomena assumed to bear some relation to friction, such as heat of wetting, interfacial tension, contact angle, deflocculation of pastes, fractionation by adsorption, change in viscosity with dilution, rectification of alternating currents, adherence to metal under centrifugal force, and penetration into porous materials. The merit of any such test can be demonstrated only by correlation with mechanical friction tests of some kind.

NUMERICAL SCALES FOR OILINESS

If oiliness is defined as that which causes a difference in friction under certain conditions, the numerical measure of oiliness might be derived mathematically in any number of ways from some combination of observations on the coefficient of friction f.

For example, if the observations are plotted in the form of an f-G curve[31] for each of two lubricants, the unknown and a reference lubricant, at least five such combinations are available. These are (1) the static coefficients, f_0 and f_0'; (2) the two values f and f' corresponding to an arbitrarily chosen value of G; (3) the two values G and G' corresponding to an arbitrary value of f; (4) the ordinates of the minimum points, f_m and f_m'; and (5) the abscissas of the minimum points, G_m and G_m'. The primed symbols correspond to the reference lubricant and the unprimed to the unknown or test lubricant. These various points are indicated in Fig. 1. Obviously, the first-mentioned combination is merely a special case of the second. Suppose the second combination has been agreed upon; there remains considerable option as to the mathematical function to be set up for expressing oiliness in terms of the two observations f and f'. Thus the oiliness X of the unknown could be taken as the difference, $f' - f$; the relative difference $(f' - f)/f'$; or the simple ratio, f'/f; in all of which f refers

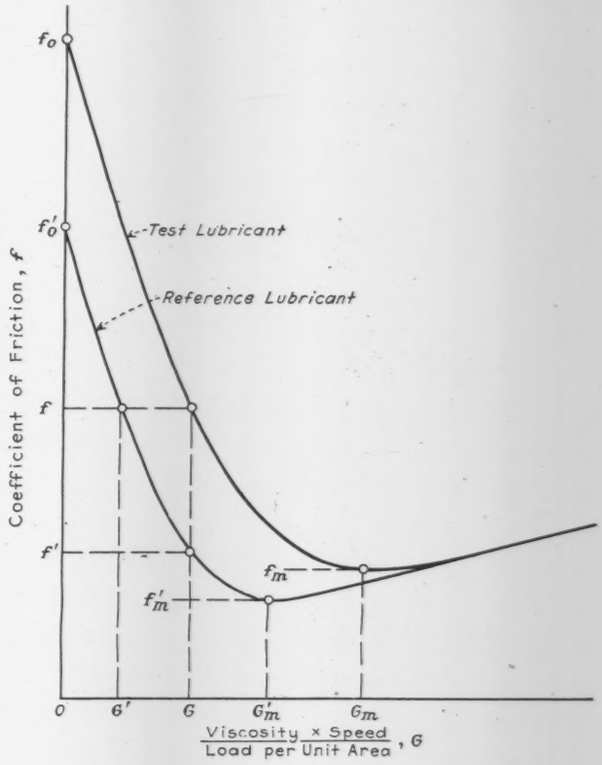

FIG. 1 CONSTANT-LOAD CURVES ON THE f-G DIAGRAM

to the unknown, and f' to the reference lubricant. It would seem reasonable to expect the ratio methods to be more reproducible than a pure difference method.

Another method, utilizing two or more reference lubricants, is analogous to the familiar calibration of thermometric scales by the use of a series of "fixed points," and might be designated as the interpolation system. On this system, if two reference fluids only are adopted, giving coefficients f_1 and f_2 at any one value of G, the oiliness X of the unknown may be taken equal to X_1 plus the fraction $(f_1 - f)/(f_1 - f_2)$ of the total difference $X_2 - X_1$. If the latter be divided into 100 equal intervals, while X_2 is designated as 100 units of oiliness and X_1 as zero, a scale would be established analogous to the Centigrade scale of temperature (Fig. 2).

Whether or not friction observations on oiliness machines can be made sufficiently reproducible to permit routine use of a numerical scale for oiliness is an unsettled question. And in speaking of reproducibility, all that is implied is that the oiliness values should check when the test conditions are completely reproduced. It is not to be expected that the oiliness of

[31] It will be recalled that G denotes the generalized variable ZN/P.

a given lubricant will be a constant for all values of G, or for all different loads at a fixed value of G. It cannot even be predicted that the relative order of excellence of a collection of three or four lubricants will be the same under all test conditions. It would be too much to hope that the inherent complexities of oiliness measurement are any less formidable than those which have been experienced in consistency measurement. For example, it is well known that one plastic material may present a stiffer consistency than a second at low rates of shear, whereas the first may be more fluid than the second at a higher rate of shear. Nevertheless, it is believed that an important step forward will have been taken when the oiliness of a lubricant at any one instant can be expressed by a definite numerical value. This would seem to be the prerequisite for any future investigation aiming to discover what relationships exist between oiliness and the chemical nature of the lubricant, or between oiliness and the practical performance of machinery.

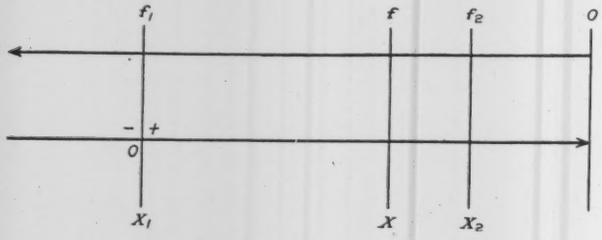

FIG. 2 OILINESS SCALE BASED UPON TWO FIXED POINTS

CORRELATION OF OILINESS WITH FRICTION OF MACHINE ELEMENTS

Granting the definition and measurement of oiliness as a reproducible characteristic not too greatly influenced by operating conditions, the question arises how to utilize the values obtained.

The situation is analogous in some respects to the utilization of viscosity observations. It calls for an experimental correlation to be mapped out, connecting the coefficient of friction[32] of the machine element, as dependent variable, with the oiliness value as independent variable. Such correlations already exist between the coefficient of friction and viscosity as independent variable. The desired correlation might be suggested, in an ideally simplified form, by Fig. 3, in which all factors except oiliness X and the viscosity at atmospheric pressure Z are held constant.

The analogy may be brought a step closer by comparing oiliness with the consistency of a non-Newtonian material like oil containing soap. The instantaneous consistency is measured by fluidity, or rate of shear divided by shearing stress. The fluidity of such a material is not a constant at any fixed temperature but depends on the rate of shear, and to some extent on the previous history of the sample as regards mechanical and thermal treatment. It may be expressed mathematically as a function of the rate of shear or shearing stress.[33] So also oiliness may prove to be a varying property whose numerical values require for their interpretation a statement of the load, speed, previous history, and other pertinent conditions.

A convenient way of dealing with a variable property like fluidity or oiliness is to replace it by an equivalent set of constant properties.[34] The first step is to formulate an empirical equation connecting the variable property with the factors on which it depends, fluidity for example being expressed as a function of the shearing stress. The coefficients in this equation form an assemblage of constant properties. As applied to oiliness, they might be termed the component properties of oiliness. In Fig. 3, the coordinate X would then represent simply one of the component properties, while the others are held constant, and the complete picture would require a family of surfaces.

In so far as the customary interpretation of Sir William Hardy's investigations is correct, it would appear that oiliness may be measured by the static coefficient alone. In that event, the correlation of oiliness with the friction of a particular machine element at constant speed and load would be completely represented, for any one viscosity, by the trace of a plane in Fig. 3 perpendicular to the Z-axis. For this purpose the numerical scale of oiliness might be chosen in any of several ways such that increasing values of X always correspond to decreasing values of the static friction.

Fig. 3 has been sketched in such a manner as to suggest that although there is an optimum viscosity corresponding to a minimum friction on the f-Z curve, there is no minimum point on the f-X curve and therefore no such thing as a lubricant possessing too high a degree of oiliness.

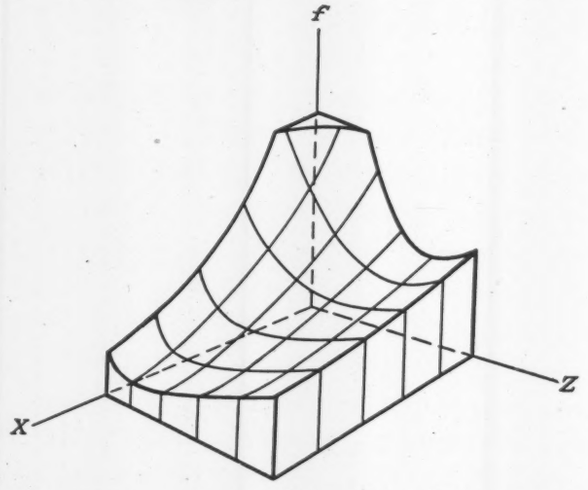

FIG. 3 IDEALIZED CORRELATION OF OILINESS X AND VISCOSITY Z WITH THE COEFFICIENT OF FRICTION f

SUMMARY

1 This paper is limited to the condition known as imperfect lubrication, where the film is so thin that the recognized laws of thick-film lubrication due to Osborne Reynolds are not directly applicable.

2 Confusion will be avoided by restricting the term oiliness to its historically accepted meaning in connection with frictional resistance, without attempting to include qualities associated with wear or seizure.

3 Oiliness is that which may cause a difference in friction between two tests, under identical conditions, in which the lubricants have the same viscosity at the test temperature and atmospheric pressure.

4 The use of material standards of oiliness may play an important part in eliminating the effect of purely mechanical disturbances, as pointed out by Kingsbury in 1902.

5 If oiliness can be reduced to a numerical scale of measurement, there will then be some solid ground to stand on when investigating its relation to the chemical nature of the lubricant, and to the friction losses in machinery.

[32] Friction losses in gears are customarily expressed by stating the efficiency of the gears in place of the coefficient of friction.

[33] M. Mooney, "Explicit Formulas for Slip and Fluidity," *Jour. Rheology*, vol. 2 (1931), pp. 210–222.

[34] M. D. Hersey, *Jour. Rheology*, vol. 3 (1932), pp. 23–29, 196–204.

The EVAPORATION *of a* LIQUID *into a* GAS—*A Correction*

By W. K. LEWIS[1,2]

IN 1922 the writer published an article under this title,[3] giving a derivation of the well-recognized formula for calculation of the humidity of a gas-vapor mixture from its wet-bulb depression, namely, $H = H_w - \frac{s}{r}(t - t_w)$. As corollaries, the derivation led to the conclusions, first, that during the process of adiabatic, isopiestic evaporation into a gas of a liquid of vapor pressure low relative to the total pressure, the so-called wet-bulb temperature of the liquid remains constant; and, second, that the ratio of the coefficient of heat transfer h of the gas to the coefficient of diffusion of the vapor through the gas k (provided vapor concentration gradients are expressed in humidity units) must equal the humid heat s of the gas-vapor mixture. The article also reported experimental data on the wet-bulb temperatures of a number of liquids in various gases, which confirmed the dependability of the formula. The accuracy of the formula for water-air mixtures has long been known.

MATHEMATICAL ERROR DETECTED IN DERIVATION OF FORMULA

Shortly after the publication of this article, study of the data in the literature on the heat conductivities and diffusivities of gases, compiled in connection with research programs on heat transmission and absorption, made it clear that, while for mixtures of water vapor and air the ratio of these coefficients was substantially equal to the humid heat, this was not in general true for other mixtures, as required by the above derivation. This situation presented a serious dilemma. In favor of the formula it could be said that its derivation and that of its corollaries seemed direct and apparently sound. Furthermore, the dependability of the formula for mixtures of air and water vapor had been checked time without number, within the experimental accuracy of the determinations. The substantial constancy of the wet-bulb temperature of any given mixture of air and water vapor during adiabatic, isopiestic evaporation was beyond question. Moreover, the formula checked the only wet-bulb data available on other mixtures, namely, that given in the article referred to. None the less, despite this experimental confirmation of the derivation, the data in the literature on diffusivities and thermal conductivities did not correspond to those required by the derivation and the differences seemed outside any probable experimental error. While this discrepancy has been studied here and elsewhere[4] for seven or eight years, it has hitherto remained unexplained.[5] It now develops that there was a mathematical error in the derivation offered. While, fortuitously, the relation holds approximately for water in air, it is not in general valid for other mixtures.

THE EQUATION INVOLVED

Visualize the saturation of a gas by adiabatic evaporation of a liquid into it under constant pressure, thereby cooling the gas from t to t_e, the liquid being supplied at the latter temperature. Using the nomenclature of the original article, an energy balance requires

$$r(H - H_e) = s(t - t_e) \quad \ldots\ldots\ldots\ldots\ldots [1]$$

Now consider the first differential step in this same process. There must be a dynamic balance between the heat diffusing into the liquid due to the temperature gradient and the heat consumption corresponding to the vapor diffusing out under the humidity gradient, represented by the equation

$$rk(H_w - H) = h(t - t_w) \quad \ldots\ldots\ldots\ldots\ldots [2]$$

These equations are correct and equivalent, but in the article referred to, the error was made in comparing them by the method of undetermined coefficients of implicitly assuming that H_w and t_w are constant in a given process, whereas in fact they are functions of H and t.

The original article offered wet-bulb data which did in fact substantiate Equation [1] for several liquids and gases. However, those data were obtained by leading the gas through a liquid in a Dewar flask, containing glass beads to increase contact. Therefore, the gas substantially saturated itself and the results necessarily conformed to the heat balance of Equation [1]. The inference that they confirmed Equation [2] was unfounded. For a long time, this laboratory has endeavored to correct this defect in experimental technique, but unexpected difficulties have been encountered. Thus, in using a wetted wick around the wet bulb, in the case of organic liquids, the heat of vaporization is so low that the volume of liquid evaporated per unit time is high. This dries the wick and raises its temperature because of the dry surface available for heat pick-up. To get a true wet-bulb reading in a large volume of air, all contact surface between bulb and air must be completely liquid-coated.

THE SOLUTION OF THE PROBLEM

The problem was finally solved by the use of the arrangement shown in Fig. 1. A is the wet-bulb thermometer. B is a tube to feed liquid to the bulb. D is a cylindrical thimble of rather dense but permeable filter paper, sealed into B at E, and closed at F with a small sealed-in plug of cork. The liquid enters at C under any desired head. If the head is low, the outside of D is not entirely wet and the temperature is high. If the head is too high, a stream of liquid flows through D and drops off at F. The sensible heat of this stream tends to warm the bulb, even though the rate of flow be low. Effort was made to pre-cool the liquid so that it would come to E at bulb temperature, but it is difficult to insulate B sufficiently. However, by locating point E well above the bulb, the liquid is pre-cooled substan-

[1] Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

[2] Received, Oct. 14, 1932.

[3] Trans. A.S.M.E., vol. 44 (1922), pp. 325–340.

[4] "Verdunstungskühlung," by Friederich Merkel. *Forschungsarbeiten*, vol. 275 (1925).

[5] This situation has, of course, been irritating, but until the reason for the difference could be made clear, it seemed the part of wisdom to adhere to the formula, supported as it was by well-authenticated scientific data and extensive engineering experience.

tially to bulb temperature before reaching it. By this technique it became possible to get consistent, reproducible wet-bulb readings in a stream of air, provided the velocity is sufficient to render radiation errors negligible.

By this method, it was found experimentally that in a wind tunnel at an air velocity of 12 fps the wet-bulb temperature of toluol is 14.5 C for a dry bulb of 26 C. In the set-up used, this reading was constant down to an air velocity of about 8 fps, below which the wet bulb began to rise a few tenths of a degree. On the other hand, air at 25.9 C blown through toluol in a carefully insulated Dewar flask reduced the liquid temperature to 7.4 C. Taking the vapor pressure of toluol at 7.4 C as 11.5 mm, the corresponding humidity is H_e = 0.0488 lb of toluol per lb of air. Using 96 calories per gram as the heat of vaporization of toluol at this temperature level, Equation [1] gives $s = 96\,(0.0488)/(25.9 - 7.4) = 0.253$, as compared with 0.238, the specific heat of air. The computed value is a bit high because the air did not become completely saturated with toluol. However, at the wet-bulb reading under conditions of negligible saturation of the air, 14.5 C, where the vapor pressure is 16.9 mm, using Equation [2] in an entirely similar manner, $H_e = 0.0722$ and $h/k = 0.60$, a value more than two and one-half fold that of s.

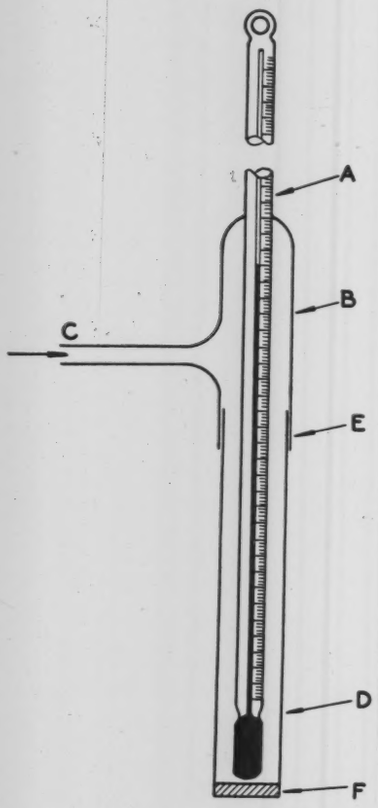

FIG. 1 WET-BULB THERMOMETER

However, this high value of h/k checks the literature data on conductivity and diffusivity satisfactorily. The thermal conductivity of air in metric units is $h' = 0.000058$ and the coefficient of diffusion of toluol through air as given by the International Critical Tables, corrected to the average film temperature of 20 C, is $k' = 0.082$. However, this coefficient of diffusion k' must be converted into the proper humidity units, in which humidity is expressed as pounds of water per pound of dry air. This is most readily done by keeping in mind the fact that the coefficient as given above represents volume of gas, measured under the conditions of diffusion, diffusing per unit of time, area, and concentration gradient, the concentration being expressed as volume fraction or mol fraction. Since concentration of the diffusing constituent is low, one can replace the mol fraction by the mol ratio. This can be transformed to weight ratio by multiplying by the ratio of the molecular weights, that of air over that of toluol, 29 divided by 92. To convert volume diffusing into weight diffusing, one must multiply by the molecular weight of the diffusing element, i.e., the toluol, and divide by the molecular volume under the conditions in question. Since the experiment was conducted at atmospheric pressure and the average temperature of the film through which diffusion was taking place was 20 C, the last figure becomes 24,060 cu cm per gram mol. It is clear that the molecular weight of the toluol cancels out, so that the conversion factor becomes 29/24,060, whence $k' = 0.000099$. Hence, $h'/k' = 0.000058/0.000099 = 0.59$, a figure closely checking the experimental figure given above.[6] One is, therefore, driven to the conclusion that the wet-bulb temperature of a given gas at definite temperature, pressure, and vapor concentration may be subject to variations within decidedly wide limits.

HUMIDITY-TEMPERATURE RELATIONSHIPS

Fig. 2 will clarify the situation. It represents diagrammatically a plot of humidity against temperature for a given gas-vapor combination. The point A represents the condition of the specific mixture in question. B is the temperature assumed by a wetted bulb around and past which a stream of gas of condition A is flowing in amount so large that the change in the humidity of the gas as it passes the bulb may be neglected.

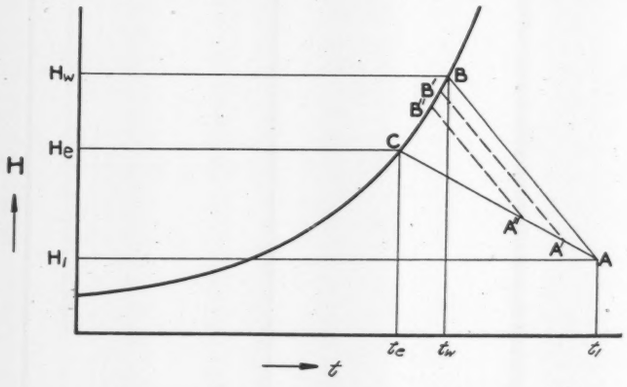

FIG. 2 HUMIDITY-TEMPERATURE RELATIONSHIPS

The temperature assumed by the bulb corresponds to Equation [2]. It is a temperature such that the diffusion of vapor from the bulb into the gas under the humidity gradient $H_w - H$ is quantitatively equivalent to the diffusion of heat inward from the gas to the bulb under the temperature gradient $t - t_w$. The point C is the final temperature which the liquid will assume if gas of condition A be brought into adiabatic, isopiestic contact with it sufficiently intimate so that the gas becomes completely saturated. The position of point C is dictated by Equation [1]. If, however, the gas at condition A is allowed to saturate itself partially but not wholly, the point A will move, not along the line AB, but along the line AC to a new condition A'.[7] In other words, the character of the change is dictated by the energy balance Equation [1]. To this new condition A', will correspond a new wet-bulb equilibrium point B', the line $A'B'$ being parallel to AB. As saturation of the gas proceeds, point A will move farther along the line AC to point A'' and point B along the saturation curve to B'', and so on, both conditions approaching saturation equilibrium at point C as a limit. In the case of water and air, the heat conductivity and coefficient of diffusion happen to be such that point B substantially coincides with point C. It would seem that the relationship here described has not been appre-

(Continued on page 573)

[6] Obviously, $h/k = h'/k'$.

[7] This assumes the specific heat of the evaporating material to be negligible in comparison with its latent heat. The obvious corrections for this effect are here omitted solely to clarify the argument.

SPECIFYING SURFACE QUALITY

A Method Based on Accurate Measurement and Comparison

By E. J. ABBOTT[1] and F. A. FIRESTONE[2]

UP TO the present time, the determination of surface quality or smoothness has largely been a matter of personal judgment, and consequently it has been subject to the same disagreements and disadvantages that determinations in such fields as heat treatment, sound, and others have experienced during periods when suitable measuring instruments were lacking and it was necessary to depend on human judgment. However, in common with these other determinations, that of the quality of a surface depends upon definite physical dimensions, and it can be described or specified in terms of these dimensions. It is the purpose of this paper to outline a specification of this kind which has been applied to a number of surfaces, and which appears to be quite practical.

REASONS FOR THE INVESTIGATION

While the need for a specification of surface quality, drawn up along standard and generally accepted lines, has resulted in the formation of an investigating committee under the procedure of the American Standards Association, it has become so urgent in some instances that individual concerns, particularly machine-tool manufacturers, have conducted independent investigations with a view to setting up some temporary standards which, in course of time, it is hoped will be embodied in a nationally acceptable scheme. The material dealt with in this paper is part of the results of one of those investigations. The management of the company sponsoring it felt that the ability to measure surface quality would result in better service to users of manufactured products and would permit a more accurate definition of the terms of contracts.

The economic aspects of surface-quality control are many, but probably the four most immediately important factors are as follows:

(1) The determination of the amount of initial wear likely to take place before securing a bearing surface which will adequately support the load without further rapid wear.

(2) The amount of machine or hand correction necessary, if any, to impart to the previously machined surface a degree of finish or accuracy, or both, which will make it acceptable for the purpose intended.

(3) The determination of the quantity and method of introduction of the lubricant designed to obviate metal-to-metal contact between the machined surfaces.

(4) The setting up of standards of quality, which, with time per piece, capital cost in dollars, delivery data, and cost of maintenance, is one of the most important items to be determined when placing a machine-tool contract, as the quality of the surface to be produced is to a large extent controlled by the number of operations and quite frequently the total time required to perform these operations is the basic and most important feature in the contract.

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[2] Assistant Professor of Physics, University of Michigan.

An investigation carried out by the Department of Engineering Research of the University of Michigan on behalf of The Ingersoll Milling Machine Company, Rockford, Ill.

TYPES OF SURFACES AND METHODS OF MEASUREMENT

It is obvious that surfaces, particularly machined surfaces, vary not only in the magnitude of the irregularities, but also in the character of the irregularities. Turned, milled, planed, ground, lapped, and other surfaces are easily recognized, and, while it may be desirable to compare the relative smoothness of different types of finish, the comparison must involve differences in the character as well as differences in the size of the irregularities.

In order to determine what characteristics of surfaces must be measured in order to specify their roughness, it is necessary to make actual measurements of the surfaces, preferably profile curves. Three sorts of surface measurements have been described in the literature:

(1) Microscopic or photomicroscopic examination of specially prepared profile sections, usually obtained by copper plating the specimen before cutting.[3,4,5]

(2) Tracing the surface with a phonograph pick-up and measuring the resultant voltage, or listening to the sound when this voltage is amplified and applied to a loud speaker.[6]

(3) Enlarged traces of the surface profile obtained by optical amplification and recording of the movements of a sharp point traced over the surface.[4,5] An instrument of this type, developed by the authors, has been called a "profilograph."[7]

The microscopic examination of sections is slow and laborious, both in the preparation of the sample and in the measurement of the records. It also destroys the specimen.

The phonograph pick-up method yields little detailed information concerning the surface. Unless the dimensions of the pick-up point, the speed of tracing, and the frequency response of the pick-up and the amplifier are known, it is very uncertain just what characteristics of the surface are measured, and without frequency analysis of the electrical output, it is practically impossible to relate the meter readings to the dimensions of the surface irregularities. Listening by ear simply replaces the human sense of seeing with that of hearing, the advantage of which is not entirely apparent.

The profilograph method is considerably more rapid than microscopic examination, does not damage the specimen, and, if properly designed, furnishes sufficient detailed information so that the essential features and dimensions of the irregularities

[3] "Microscopical Examination of Cross-Section of Surfaces," C. B. Sawyer. Appendix 1 to paper cited in footnote 6.

[4] "Über Glätte und Ebenheit als physikalisches und physiologisches Problem," G. Schmaltz. *Zeitschrift des Vereines deutscher Ingenieure*, vol. 73 (1929), no. 41, p. 1461.

[5] "Untersuchung verschiedener Methoden zur Bestimmung der Unebenheiten (Rauhigkeiten) von Metallflächen," von der Sächsischen Technischen Hochschule zu Dresden zur Erlangung der Würde eines Doktor-Ingenieurs genehmigte. Dresden, 1931. Abstract of this thesis entitled "Quality of Metal Surfaces," by John Gaillard, *American Machinist*, vol. 76 (1932), no. 36, p. 1149.

[6] "A Survey of Surface Quality Standards and Tolerance Costs Based on 1929–1930 Precision-Grinding Practice," R. E. W. Harrison. Trans. A.S.M.E. (1931), paper no. MSP-53-12.

[7] "Test for Smoothness of Machined Finishes," F. A. Firestone, F. M. Durbin, and E. J. Abbott. *Metal Progress*, vol. 21 (1932), no. 4, p. 57.

can be determined. The method of specification outlined in this paper is based on profile records obtained by the profilograph, although it could also be applied to photomicrographs of sections.

It would be convenient if the roughness of a surface could be specified by a single number, and this could probably be done if all surfaces were similar in character, and varied only in the size of the irregularities. Experience shows that every different type of surface has a characteristically different shape of profile curve, a result which is consistent with ordinary visual appearance. Consequently, it seems quite certain that more than one number will be required to give a satisfactory rating of the roughness of a surface. Space does not permit a discussion of the drawbacks of the various inadequate schemes considered by the authors. The method of approach which appears to be most practical is outlined.

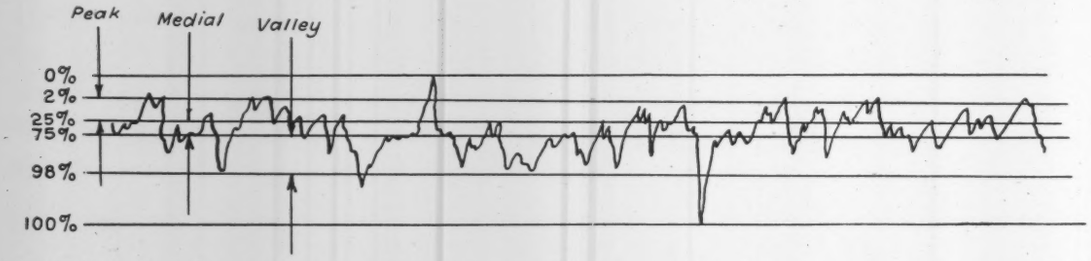


FIG. 1 TYPICAL SURFACE PROFILE SHOWING HOW THE DEPTH VS. BEARING-AREA RELATION CAN BE DETERMINED BY THE FRACTION OF THE LENGTH OF A LINE WHICH LIES IN METAL AT VARIOUS POSITIONS

THE DEPTH VS. THE BEARING-AREA CONCEPT OF ROUGHNESS

When two newly machined surfaces are placed together, they touch only on the peaks of the highest irregularities, and the actual contact area is very small. If the surfaces are "run-in" under load, or otherwise fitted, the projecting irregularities are gradually removed and the actual area of contact is increased. At first, the wear is quite rapid, but it decreases as the contact area increases. Consequently, the roughness of surfaces is closely related to the amount of wear required to procure a given percentage of actual contact area, and the following method of roughness rating is of particular significance because it is based upon this relation.

Suppose that we have a means of determining the bearing area of a given surface when in contact with a flat plate. Now let us imagine that a perfectly smooth cut of known depth is taken so that part of the roughness is removed. The bearing area is then measured, and a second cut is taken. This process is repeated until the cut reaches the bottom of the deepest valley in the original surface. The changes in bearing area which accompany the successive cuts furnish a means of describing the roughness of the original surface in much the same manner in which contour lines are used for describing geographical characteristics.

For example, suppose that Fig. 1 represents a profile curve of a surface. Now imagine a line drawn parallel to the surface just passing through the highest peak of the profile curve. This line is marked 0 per cent because it just touches the curve at one point and none of the line lies in metal. Now imagine that the line is moved down so that it lies partly in the metal. The positions marked 2, 25, 75 per cent, etc., represent positions where the indicated fraction of the length of the line lies in metal. Finally, as the line reaches the deepest valley in the profile, 100 per cent of it lies in the metal.

The relation between the position of the line and the fraction of its length which lies in metal can be used to describe the roughness of the surface. In other words, this is the relation between the depth of cut and the percentage of bearing area of the surface. It has been found convenient to plot a curve showing this relation for the surface under consideration, but this is not essential to the concept.

ROUGHNESS SPECIFICATION

A system of numerical roughness specification based on the depth vs. bearing-area relation has been worked out and tested on several dozen actual surfaces of various kinds. Figs. 3 and 4 show a group of typical surfaces ranging from an optical flat to a rough-boring operation. These are full-scale reproductions of about one-third of the length of the original records. The horizontal scales are the same in both figures, but the vertical scale is four times as great for the smoother surfaces. It will be noted that the irregularities are not shown in their true proportion on account of the smaller magnification in the horizontal direction. This is a great advan-

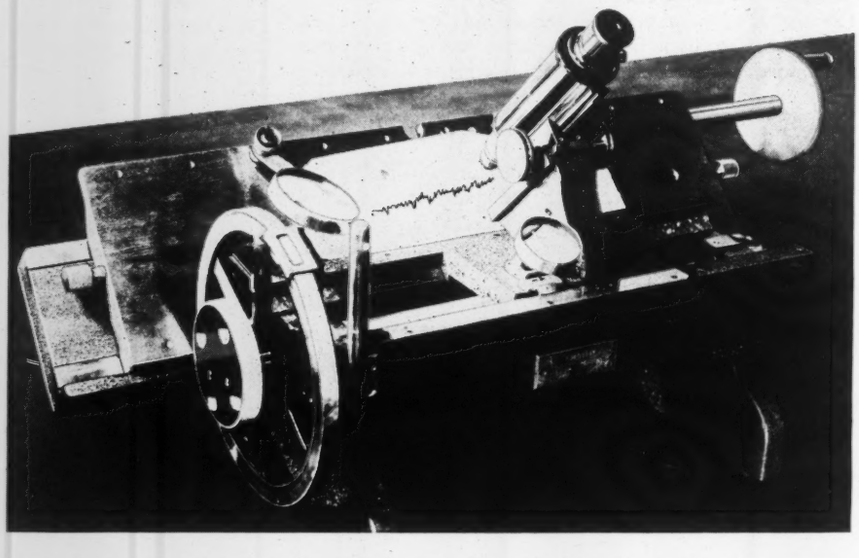


FIG. 2 COMPARATOR USED FOR MEASURING PROFILE RECORDS TO DETERMINE DEPTH VS. BEARING-AREA RELATIONS

tage in this type of record as it allows a large amount of surface to be recorded on a chart of convenient size. The records shown represent about $^3/_{32}$ in. on the sample, and if the horizontal magnification were also 2000 to 1, the record would stretch out to more than 15 ft.

The depth vs. the bearing-area relations for these graphs were measured on a comparator ordinarily used for measuring spectroscopic plates. A simpler device could be constructed, but this one was available. As shown in Fig. 2, it consists essentially of a moving stage upon which the record is mounted, and a low-power telescope with cross-hairs. The microscope can be moved longitudinally by means of a calibrated screw, and the stage can also be moved longitudinally by means of a second screw. The record to be measured is placed so that the cross-hairs come at a convenient height on the profile, and the readings of the two screws are noted when the microscope is at one end of the section of profile to be measured. The stage is then moved horizontally, and the line of sight traced along one of the lines of Fig. 1. When the profile curve is above the cross-hair, the microscope is moved by its micrometer screw, and when the profile curve is below the line of sight, the stage is moved by the other screw. At the end of the measured length, the fraction of the line of sight which lies in metal is determined by the screw readings. The record is then shifted vertically by a known amount, and the percentage

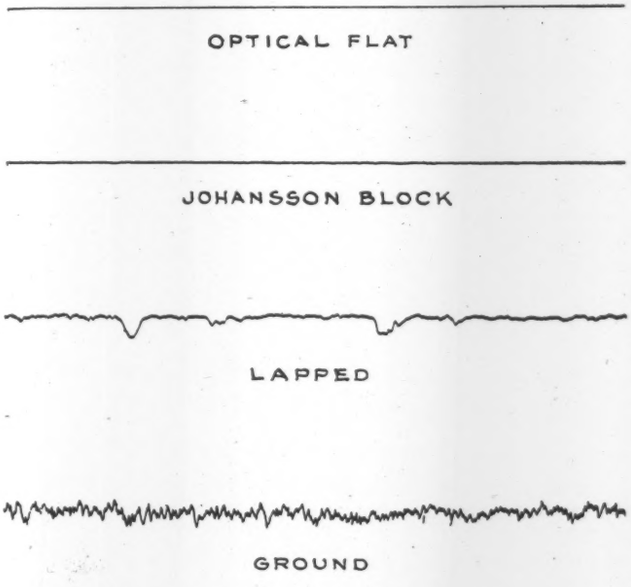


FIG. 3 REPRODUCTION OF SECTIONS OF PROFILOGRAPH RECORDS OF SEVERAL SMOOTH SURFACES

(Magnification: vertical, 2000 to 1; horizontal, 30 to 1. Vertical, $^1/_{64}$ in. = 8 millionths in.; horizontal, $^1/_{64}$ in. = $^1/_2$ thousandth in., approximately.)

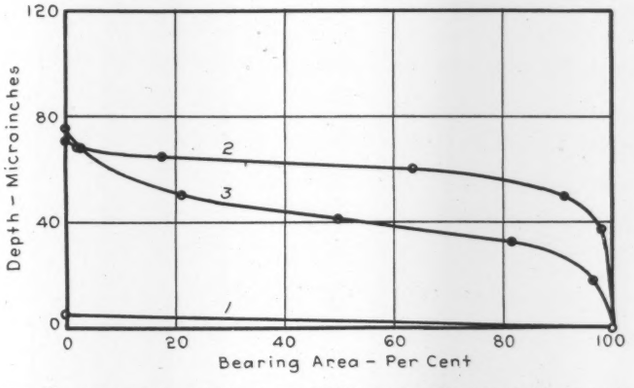


FIG. 5 DEPTH VS. BEARING-AREA CURVES FOR THE SURFACES SHOWN IN FIG. 3

(See Table 2 for roughness numbers. 1 = Johansson block, 2 = lapped surface, 3 = ground surface.)

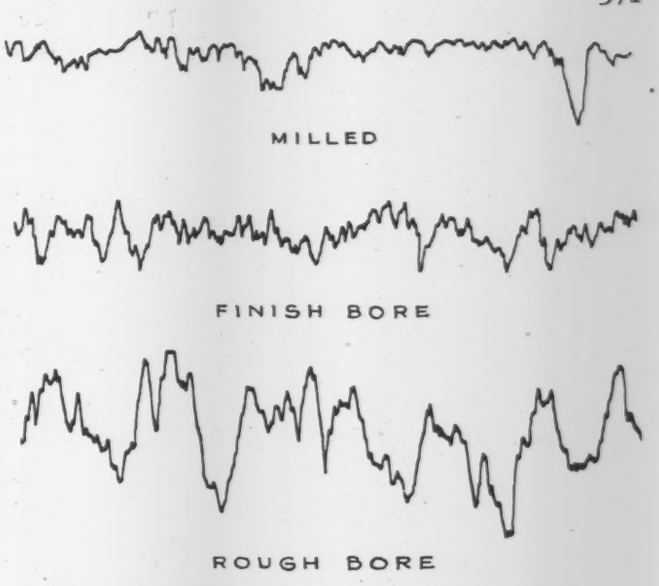


FIG. 4 REPRODUCTION OF SECTIONS OF PROFILOGRAPH RECORDS OF SEVERAL TYPICAL MACHINED SURFACES

(Magnification: vertical, 500 to 1; horizontal, 30 to 1. Vertical, $^1/_{64}$ in. = 31 millionths in.; horizontal, $^1/_{64}$ in. = $^1/_2$ thousandth in., approximately.)

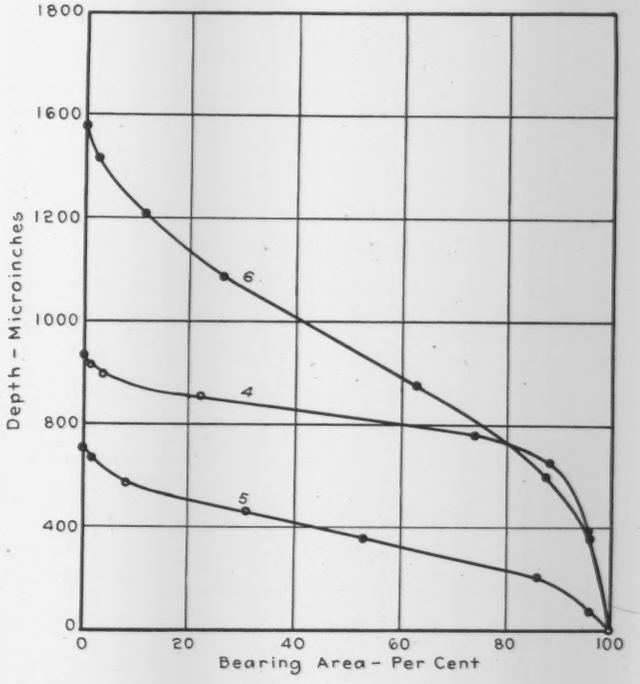


FIG. 6 DEPTH VS. BEARING-AREA CURVES FOR SURFACES SHOWN IN FIG. 4

(See Table 2 for roughness numbers. 4 = milled surface, 5 = finish bore, 6 = rough bore.)

of bearing area at this new level determined. Sufficient points are taken to determine the depth vs. bearing-area curve.

Figs. 5 and 6 show the depth vs. bearing-area curves for the surfaces shown in Figs. 3 and 4. It will be observed that all of the curves consist of an essentially straight section extending from about 20 per cent to 80 per cent of bearing area, with more or less curved sections above and below this straight central portion. This is typical of all of the 60-odd curves measured thus far.

It was also observed that the fraction of the total depth of profile occupied by each of these three parts of the curve varied greatly among the different surfaces. For example, if the profile consisted principally of scratches in an otherwise fairly smooth surface, the upper curved section was very small as compared with the lower one. These three parts of the profile have been called the peak, medial, and valley portions, and it appears to be convenient to use a number for specifying the depth of each of these three parts of the profile.

The medial section of the profile, which is believed to be the most important of the three, has been taken as the depth from the 25-per cent to the 75-per cent bearing area. The peak section is taken from the 2-per cent to the 25-per cent area, and the valley section from the 75-per cent to the 98-per cent bearing area. At first thought, it might seem that the peak and valley sections should be taken from the 0-per cent to the 25-per cent and the 75-per cent to the 100-per cent bearing area, respectively, but this does not appear to be practical. Examination of the records of actual surfaces shows that in almost every case there are very occasional peaks and valleys which are much larger than the ordinary ones, and which do not appear to be representative of the surface. Since the 0-per cent and 100-per cent points are determined by these unusual irregularities, this would place too much emphasis on them. The selection of 2 and 98 per cent does not entirely eliminate the effects of occasional large irregularities, but it does introduce an averaging effect which appears very desirable. For convenience, these values are tabulated.

The roughness of a surface can be specified by the three numbers listed in Table 1. Distances are measured in microinches,[8] perpendicular to the surface for the three sections of the profile.

TABLE 1 ROUGHNESS SPECIFICATION

Peak roughness,	P =	distance from 2% to 25% of bearing area
Medial roughness,	M =	distance from 25% to 75% of bearing area
Valley roughness,	V =	distance from 75% to 98% of bearing area

TABLE 2 ROUGHNESS NUMBERS FOR SIX TYPICAL SURFACES

	Microinches		
	Peak 2%–25%	Medial 25%–75%	Valley 75%–98%
Johansson block	1	3	1
Lapped	4	7	20
Ground	22	17	20
Milled	110	140	540
Finish bore	180	220	220
Rough bore	440	630	510

Obviously, additional numbers can be specified as desired, such as the total depth of the profile (from 0-per cent to 100-per cent bearing area), or the number of times the curve crosses some line, such as the 50-per cent bearing area line in a given distance, or other factors. Table 2 shows the roughness numbers for the surfaces discussed.

[8] One microinch = 0.000001 in.

CONCLUSION

This method of specifying roughness appears to satisfy the following essential requirements:

(1) The specification is made in terms of definite and familiar units, inches, so that there can be no misunderstanding as to the units used by different observers and no uncertainty as to relative standards.

(2) The specification deals directly with the physical dimensions of the irregularities, and is based on the familiar and important concepts of depth of cut and percentage of bearing area.

(3) The specification is simple, so that it can be used in the shop. If surfaces are of similar type, it is probable that the medial roughness number alone will suffice; if they are different, the essential differences can be described in terms which measure the peaks and valleys, both familiar to every mechanic.

(4) The method is flexible. If the three numbers listed do not sufficiently describe a given surface, additional dimensions can easily be specified.

(5) A comparatively large amount of surface is included in the roughness determination, and a large number of individual irregularities have a part in determining the rating. Unusual peaks and valleys are not neglected in making the summation, but the rating is not based too fully on these unusual values, which an inspection of records of actual surfaces shows do not truly represent the surface.

(6) Neither the making of records nor the determination of roughness numbers from them is a very lengthy process compared to plating, polishing, and photomicrographing sections. On the other hand, it is not as simple as a micrometer measurement, and the authors foresee considerable opportunity for improving the equipment for making roughness measurements.

STRAIGHT cylindrical work without heads can be centerless ground in any length up to approximately 24 ft by the through-feed method. This work, whether it is short or long, should be straight before passing through the machine. Especially is it that before centerless grinding long bars be machine straightened, or at least straightened to the same degree as obtained by machine straightening.

If the long bars are not straight before grinding they will whip both on the entering and leaving sides of the wheels and the work will make contact with the corners of the grinding wheel, thus causing spiral marks to appear on the ground surface of the bar. Long bars up to 4 in. in diameter by 24 ft long have been successfully ground by the centerless method. When grinding bars of such length, it is necessary, of course, to provide auxiliary supports at both front and rear of the machine, in order properly to support and aline the bar before it enters and after it leaves the grinding cut.

Steel tubing, as well as solid steel bars, can be satisfactorily ground by this method. Some steel tubing having a wall thickness sufficiently strong to eliminate distortion under the grinding cut can be ground with practically the same depth of cut as that used on solid steel bars. Other tubing with a light wall thickness must be ground with a greatly reduced depth of cut per pass through the machine. Thus, for the same stock removal on thin-walled tubing as on thick-walled tubing, it is necessary to pass the work through the machine a greater number of times, which, in turn, reduces the net production obtainable.—A. D. Meals in *The Iron Age*, August 10, 1933.

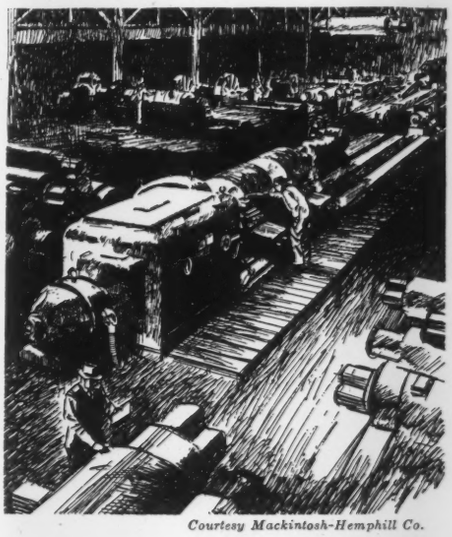
The Communication Revolution

(*Continued from page 538*)

day varied programs with features of every sort. On special occasions, we can hear King George opening Parliament, Pope Pius extending a worldwide blessing, the League of Nations indicting Japan, and a Japanese commander explaining things away from Mukden. The promised development of television will make the radio even more effective. The chief implied danger in these forms of "mass communication" is that their great influence may be abused by small groups which control them.

"A SHRUNKEN PLANET"

The quiet university village of Princeton affords a unique opportunity to observe the various stages of the Communication Revolution. Its main street has been for more than two centuries a part of America's most important highway, the main artery connecting North and South. Originally an Indian trail, it became the post road and the King's Highway, while Princeton, just midway between New York and Philadelphia, gained early prominence as an overnight stopping place. At present, more passengers and freight are probably carried past Princeton in a single week than in the whole colonial period. That old highway is now one of eight parallel lines of communication running within a few miles of Princeton. Over these pass most of the Southern traffic and a good share of the Western as well. Some 12,500 automobiles daily travel over the old highway and the newer, straighter road two miles away. There are two railroads, the Pennsylvania alone in 1929 carrying daily past Princeton some 20,000 passengers and 40,000 tons of freight. The main-trunk telegraph and telephone lines follow this route also, while flashing beacons on the horizon mark the route of the Southern air mail. Finally, as a relic of the past, there is a moribund canal, once busy with the coal trade. In addition to these eight regular lines, wireless telephone messages are sent to Europe and South America from a station on the outskirts of the town, removed as far as possible from the disturbances of New York, whose metropolitan area is encroaching upon Princeton from the other side. We receive fresh editions of New York and Philadelphia newspapers several times a day and share with the rest of the world the advantages of moving pictures and radio. Even the University is involved in the movement, for a third of its invested funds are securities of railroads and other forms of communication.



Courtesy Mackintosh-Hemphill Co.

The Age of Speed has resulted, as Jack London remarked, in "a shrunken planet and an expanded humanity." There are times when we may long for the peaceful isolation of the eighteenth-century village, yet these changes have become such a part of our existence that their absence would soon become more maddening than their presence. How far the movement will go, we cannot predict—at least we are becoming more blasé about the new developments than were our ancestors. A scientific colleague at Princeton is plotting the rate of speed increase to find when man may be able to reach the moon. A French student of the problem suggests an interesting possibility. Man at present, he says, boasts proudly, "There is no more distance!" A century hence he may be pacing the earth like a caged beast, and after crying desperately, "There is no more distance," may exert his ingenuity to recreate the space which he has destroyed.

The Evaporation of a Liquid Into a Gas—A Correction

(*Continued from page 568*)

ciated hitherto, largely because of the fact that wet-and-dry-bulb thermometry is rarely if ever applied to mixtures other than water in air.

It is imperative to differentiate between the two points *B* and *C*. Carrier called *C* the *point of adiabatic saturation*, and this term, while not completely descriptive, may well be retained. The point *B* may be designated as the wet-bulb temperature, but it must be kept in mind that it has definite significance only in case the quantity of gas flowing past the bulb is such that the change in its humidity due to evaporation from the bulb is negligible.

Because of the difficulty of supplying liquid to the bulb at wet-bulb temperature, it seems not unlikely that, where one wishes to use the temperature depression of the liquid to determine the humidity of the mixture, experimentally it will be best to determine point *C*. This can be done by the use of a Dewar bulb as a container for the liquid, with proper provisions against thermal errors and for saturation of the gas. However, the point conditions encountered in the engineering problems of drying, humidification, and the like, will always be found to correspond to point *B*.

CONCLUSION

In conclusion, it must now be recognized that the wet-bulb temperature of adiabatic, isopiestic evaporation of a liquid into a gas is not in general constant as has hitherto been assumed, although it is fortuitously substantially so for water in air. The temperature in the early stages of the evaporation is dictated by the coefficients of heat conductivity and thermal diffusivity, but the end-point of the process is fixed solely by the energy balance.

MECHANICAL ENGINEERING

Vol. 55 SEPTEMBER, 1933 No. 9

GEORGE A. STETSON, *Editor*

The E.C.P.D.

READERS may well accustom themselves to these four letters as they will be found frequently in these pages. They stand for the Engineers' Council for Professional Development, a joint comprehensive endeavor of seven engineering associations that holds great promise for the profession. At Chicago particularly, whenever discussions, formal and otherwise, turned on the problems of the profession, the greatest enthusiasm was expressed in the possibilities that are inherent in the program and policies of this body. So much is hoped to be accomplished by means of it—and the times are particularly ripe for the performance of the services it is set up to render—that skilful and energetic handling will be necessary to avoid disappointment.

Four strong committees, representing in a comprehensive manner the objectives of the Council, are beginning to think about their individual functions and programs. The charter was recently approved by the participating bodies, and a meeting for formal organization will take place in the fall. In the meantime, those who wish to refresh themselves on what the Council hopes to do should reread C. F. Hirshfeld's statement in the September, 1932, issue of MECHANICAL ENGINEERING.

A Problem in Self-Analysis

INSTITUTIONS, like individuals, from time to time become critical of themselves and their objectives. They rub elbows with misfortune, their complacency is disturbed, and they are led to severe struggles to retain their economic status. Faced with the necessity of retrenchment, they must reassess practises and objectives, and reaffirm policies and aims.

For many months, The American Society of Mechanical Engineers has been faced with the problem of self-analysis. Other institutions—Federal, state, municipal, educational, commercial—are also facing it. Intellectual honesty and good sense, free from Pharisaic blindness and Bourbon stubbornness, will make possible an appraisal consistent with the facts of the situation. Already a Special Committee on Policies and Budget, appointed by the Society's Council, has made a thorough study of existing conditions and has presented a report upon which action has been based. The committee's work is only partially completed, for there remains the more fundamental problem of charting a course for the years that lie immediately ahead to supplement the specific actions affecting the coming year. In this larger task, every engineer can be of help by stating his views, offering his criticisms, and making as honest an attempt to face the facts as the committee has done. All friends of the Society can be of great assistance to it now by letting the committee know what activities, in their opinion, are important and what are unimportant. The chairman, Harry R. Westcott, will be grateful to any who wish to express themselves on this important matter and assist in making the Society's self-analysis truly representative. His address is 139 Orange Street, New Haven, Conn.

Jobs for Himself and Others

THE MAN who makes a job for himself is likely to be economically independent: the man who also makes jobs for others becomes a public benefactor. Engineering holds opportunities for both. To imaginative men, engineering methods of work may be as important as experience in a given field or position when jobs are limited. The man who thinks of himself as a designer or an operator of power plants, for example may have difficulty in locating himself when jobs are scarce, but skill in engineering methods of work may make him a useful and valuable employee in a position not usually held by engineers, or in a position which can be created out of an unfilled, and sometimes unsensed, need and his ability to discover and fill that need. This is a case for the marketing of engineering services. It requires the imagination to hunt out the need, the capacity to devise a means for meeting the need, and a carefully prepared campaign to market the idea—and the personal services that are part of it. An engineering training will provide some, but not all, of these requirements.

More Work for the A.S.A.

AN EXCHANGE of correspondence between Secretary of Commerce Daniel C. Roper and Howard Coonley, president, American Standards Association, has prepared the way for the transfer to the A.S.A. of five sections of the National Bureau of Standards. These are the Division of Trade Standards, the Division of Specifications, the Division of Simplified Practise, the Building Code and Plumbing Code sections of the Building and Housing Division, and the Safety Code Section. The transfer, in the words of Secretary Roper, "undertaken in the belief that these functions should be in the hands of industry and consumer groups, is being carried out as part of the Government economy program."

When there exists an experienced and well-organized agency, such as the A.S.A., which is representative of industry and the consumer, and which has such an honorable record of successful achievement to its credit, such work as the Department of Commerce has been doing in the sections that are being given up can safely be turned over to it. Many persons will see in this opportunity

which is being offered to the A.S.A. a hopeful sign that the Government is willing to let industry look after some of its common problems. While the cost of doing the necessary work will be eliminated from the departmental budget, it will have to be assumed by those who support the work of the A.S.A. Industry will probably be better satisfied to make the contribution directly for work done under its own procedure than indirectly through a tax-supported Government bureau. If the interests of all who are involved in industrial standardization are impartially and sympathetically guarded, the new arrangements should prove an interesting and convincing adventure in industrial self-government.

Production and Purchasing Power

PROFESSOR NORMAN, in an article under this title to be found elsewhere in this issue, redirects attention to the vexing problem of production and purchasing power and to the reports of the American Engineering Council's Committee on Economic Balance. Many readers of MECHANICAL ENGINEERING have felt, no doubt, with Professor Norman that the second report of the A.E.C. Committee was too inconclusive and cautiously worded to be satisfying, and that it had vitiated, somewhat, the strength of the belief given such a prominent place in the first report, that withheld purchasing power made the balancing of consumption and distribution impossible and that the remedy lay in taxation and borrowing for public works. Inasmuch as Professor Norman expresses this line of thought constructively by offering statistical evidence to support it, he not only contributes to our understanding of this point of view but he keeps alive our interest in the reports and the committee's work.

It was one of the vigorous characteristics of Malthus, to whom Dean Kimball directed our attention so opportunely last month, that he criticized his fellow economists for falling a prey to oversimplification in their explanation of matters that are far from simple. This may be a fair criticism of the Committee's first report, and of Professor Norman's amplification of the income-distribution theory. This is borne out in the second report of the Committee where it was admitted that the problem and the solution were much more complex than originally imagined.

Nor must we forget Professor Slichter's warning in discussing this view in the February issue to the effect that "the fact that lack of adequate consumer purchasing power is one of the results of depressions does not, of course, mean that it is one of the causes. . ." Mr. Flanders, the chairman of the A.E.C. committee himself admits that "the difference in character between the first and second reports . . . . . was due to a growing realization that the first report came to conclusions that were too easy, and that had left out elements of primary importance. The element of primary importance that was left out was that complex of causes dependent on the very elastic nature of our money supply."

Professor Norman's paper and Mr. Flanders' reference to the monetary aspects of the problem are both significant. The NIRA and the Administration's policy of building up purchasing power as a means of accelerating recovery lend support to the view Professor Norman takes. Undoubtedly, the view appeals to the majority to whom it is expressed. There is danger, therefore, that in acceding to it we blind ourselves to other causes of recurring crises. We must not overlook the monetary aspect of this complicated problem. Nor are we likely to do so, as it is before the entire world today as never before. In another phase of the Administration's program we may find ourselves coming to grips, in a very realistic fashion, with some of the monetary theories that Acts of Congress have made it possible for the chief executive to try.

No one can say that these subjects are not of importance and vital interest to engineers and that economic truth should not be permitted to dawn wherever it may.

What Is Engineering?

NO ATTEMPT is here contemplated to present one of those succinct acid-proof and dust-tight definitions of engineering with which every engineer at one time or another busies himself, for it is in definitive moods that engineers become too narrowly analytical and fail in imagination. The fields to which attention is here directed lie outside and beyond, and not within, the limits of all but the broadest of such definitions of engineering.

In the material world there is but little that does not concern the engineer. Everything is a monument to his achievements, a challenge to his skill, or a means through which he is actively expressing himself. Not everything is equally important, but little is irrelevant. The microscope is a useful instrument, but it would be too bad if it blinded the eye of the metallurgist to the turbine rotor or the bridge span, or to the regions which the turbo-generated electricity and the bridge served, or to the people whose lives were affected by them. Engineering will not fail because of lack of intensive cultivation, but because the seed will be planted on fields too small to yield a sufficiently abundant harvest.

Our plea is that the engineer will not ask the question, "What has that to do with engineering?" but that he will provide the answer to it by demonstrating that his skill can fruitfully apply science for the benefit of mankind. The man whose imagination is stirred to engineering achievement by none but the familiar symbol of the cog-wheel is not likely to provide for himself or others many new jobs or benefits because they may not represent engineering as he senses it. What the world needs is not more cog-wheels but more engineers who have the initiative and resourcefulness of the man who devised the cog-wheel and lesser developments. Articles and illustrations in MECHANICAL ENGINEERING are published not only to invite critical analysis of technical details, but also to stimulate speculative and creative minds to make necessary broader conceptions of what is engineering.

SURVEY OF ENGINEERING PROGRESS

A Review af Attainment in Mechanical Engineering and Related Fields

ENGINEERING MATERIALS (See also Metallurgy: Creep and Structural Stability of Nickel-Chromium-Iron Alloys at 1600 F)

Electrical Insulation of Concrete

THIS concrete is made from a mixture of sand and cement with a little water and the addition of a special bituminous emulsion. The grain sizes of the sand and gravel must be particularly carefully controlled and must be properly selected, as the presence of certain materials, even in small quantities, affects the results disastrously. The French Chalk and Cement Co., of Lafarge and Tiel, developed a special cement for this purpose. Moreover, in the manufacture, extreme care must be used to obtain the highest possible compactness with a minimum of water. The hardening of the cement must also be carefully controlled, and when it has advanced to the proper point, a thermal treatment, followed up by varnishing, makes it possible to regularize the properties of the material and to prevent their change.

Heat treatment and varnishing of the material are particularly necessary in the case of insulators placed in the open, but may be omitted in certain applications. It is claimed that this concrete, developed since 1928 by E. Lambert, has high insulating properties, the figures being given in the original article. (T. Ferrier, President of the Association of Manufacturers of Reinforced Concrete Posts, in *Revue Générale de l'Electricite*, vol. 33, no. 22, June 3, 1933, pp. 731–733, *d*)

Oil-Permeable Metal Alloy

THIS article describes a patented material and the full details of the method of manufacture are not disclosed. Broadly, a typical alloy contains 90 per cent copper and 10 per cent tin, the material is pure virgin metal in the form of fine powder, and the desired proportions are mixed together and briquetted under high pressure in proper dies. The brittle mixture is then subjected to a sintering process at a temperature varying with the mixture used. The sintering temperature is well below the melting point of copper but above that of tin, so that a perfect alloying takes place. The heating causes a slight growth of the material for which due allowance is made. Air is expelled from the alloy and is replaced by lubricating oil. It is claimed that if a bushing of this material (called oilite) is allowed to stand, it does not drop oil. The material can actually be substituted for the wick in an ordinary kerosene lamp. In use, however, initial friction or slight warming induces the oil to the surface. It is said that if the temperature is increased sufficiently the oil will exude, only to be completely reabsorbed on cooling again.

A more striking test is to squeeze a bushing in a vice endways until it is deformed. The amount of oil exuded due to the closing up of the capillary tubes is astonishing, and what is of equal importance, the bushing will not break, but will belly out until barrel shaped, thus proving its great ductility, despite its porosity.

Data of oil consumption with bushings of this kind are given in the original article, where it is said that oil grooves or oil holes in the bearings are unnecessary. Details of manufacture of bearings are given. (R.N.R. in *Machinery* (London), vol. 42, no. 1078, June 8, 1933, pp. 282–284, illustrated, *d*)

FOUNDRY

Manufacture of Centrifugally Cast Piston Rings

THIS is a description of the work of the British Piston Ring Co., Ltd., at Coventry. The centrifugal casting machine is shown in the original article. It is of the horizontal-axis type with a front plate determining the inside diameter of the casting. The rate of cooling of the casting is relatively high which is claimed to give a close-grained material with excellent elastic properties. The sleeve is cast with a four-cornered base at the end to be held while the casting is being machined. This base is passed through the square hole in a chucking plate and is then given one-eighth of a turn, thus allowing the plate to grip it without necessitating the removal of the plate every time a new casting is introduced. The machining is done by means of a boring bar carrying a cutter with turning and boring tools, the machining itself being done on a lathe.

To relieve the machining and casting stresses, the piston rings undergo heat treatment, after which they are ground on their sides and finished to their finish dimensions by grinding, honing, or lapping. The special gages are described. It is claimed that results so far obtained indicate that hardened and tempered piston rings are of considerable help in connection with cylinder wear, especially when the cylinder liners themselves are of hardened and tempered centrifugally cast iron.

The fallacy that rings should not be harder than the cylinder has been exploded long ago. In considering the matter, one has to think only of the wearing surface of the ring compared with that of the cylinder. It has, however, been proved that rings of a comparatively soft nature hold metallic and siliceous particles which cause abrasion of the cylinder walls. Properly hardened and tempered rings do not hold these particles embedded in the same way. (*The Commercial Motor*, vol. 57, no. 1471, May 26, 1933, pp. 536–538, 10 figs., *d*)

Die-Casting Iron and Steel

SINCE the first of this year, an automatic die-casting machine has been put into practical operation in the production of cast-iron camshafts. The authors make a distinction between die-casting and permanent-mold casting on the basis of pressure.

The die-casting of iron differs materially from the usual method of permanent-mold casting. The machine known as the "Cast-o-matic" was designed by A. W. Morris and is now in commercial operation at a large Pennsylvania manufacturing plant. Castings weighing from 50 to 250 lb and up to 8 ft long have been successfully produced on it, and the normal capacity is 5 tons of simple castings an hour. A controller unit, which may be located at any convenient distance, controls all operations. It is a cam-operated multiple-valve device having

18 cams which hydraulically regulate all operations with close accuracy. Metal from a sealed container is forced up into a mold at a varying rate of flow, starting slowly and winding up fast, thus intensifying the pressure as the mold is nearly filled and driving the metal into all corners of it.

Provided molten iron of the proper analysis and temperature is delivered so that there is always a supply in the reservoir and the annealing-oven temperature is maintained correctly, the process is automatic.

The details of the operation of the machine are given in the original article. Not all irons are suitable for die-casting, and, in general, the experience indicates preference for electrically melted iron. Nitrided cast iron and stainless steel have been handled successfully. A high quality is claimed for such die-casting.

The matter of molds is still under development, but it is said that under favorable conditions the molds used in die-casting of iron will show a comparatively long life and relatively low cost. (A. W. Morris and Herbert R. Simonds, in *The Iron Age*, vol. 131, no. 26, June 29, 1933, pp. 1028–1030, and advertising section p. 14, illustrated, *d*)

FUELS AND FIRING (See also Testing and Measurements: A Method for Rating the Grindability or Pulverizability of Coal)

Correlation Between Calorific Value and Density of Fuel Oils

THE object of these tests was twofold: First, to determine whether or not the Sherman and Kraff formula (modified) as given in article 38–47 (5) of Manual of Engineering Instructions, U. S. Navy, gives a correct correlation between the calorific value and density of fuel oils; and second, if this formula is not correct, to derive one that is correct. A plot of observed densities and calorific values of oils received at the Naval Boiler Laboratory during the past two and a half years shows that in all cases but one the Sherman and Kraff formula predicted too high a calorific value for a given density. The results of calculations were compared with a calorific value of fuel oils actually obtained by calorimetry.

The particular interest of the paper, aside from the practical results, lies in the portion dealing with the application of statistical methods to the determination of the formula expressing the correlation between two variables, including the discussion of the matter of coefficient of correlation.

An appendix contains a computation of measures of relationship between the two variables, degrees A.P.I. and Btu per lb, and another appendix gives the details of determination of the probable error (or standard error) of measurements of calorific value.

The following formula is considered to be correct, and the report recommends that it shall be known as the Naval Boiler Laboratory formula (1933) for correlation of calorific value and density of fuel oil. It is recommended that the formula be verified, and, if necessary, modified, every two years. The formula is Btu per lb = 17,687 + 57.9 (A.P.I. at 60 F).

The coefficient of correlation for that formula is:

$$y = +0.912 \pm 0.016$$

For oils near 18,500 Btu per lb, this formula, 68 per cent of the time, predicts the true calorific value within ± 0.7 of 1 per cent; and 95 per cent of the time within ± 1.4 per cent. (Commander Lybrand Smith, U.S.N., Report NBL. Test No. 2132, Naval Boiler Laboratory, Navy Yard, Philadelphia, Pa., 10 pp. and 3 plates of illustrations and tables, *e*)

INTERNAL-COMBUSTION ENGINEERING (See also Measuring Instruments: Lunken High-Speed Diesel-Engine Indicator)

Processes in a Gas Turbine, With Special Reference to Pressure Firing

IN AN internal-combustion turbine, the gases must be cooled more than in a reciprocating-piston engine, as the blading cannot stand the higher temperatures.

In the Holzwarth gas turbine, as much work is recovered from the steam as is required for the compression of the gas-air mixture. If L_{ue} and L_{ve} denote respectively the effective work of the steam turbine and the gas turbine, and L_{ke} the required effective work for compressing the materials of combustion (air, fuel gas, liquid gas, etc.), then the useful work will be

$$L_n = L_{de} + L_{ve} - L_{ke} \quad [1]$$

and in the limit in the case of a gas turbine,

$$L_{de} = L_{ke} \quad [2]$$

and

$$L_n = L_{ve} \quad [3]$$

In an ordinary steam plant, combustion takes place at a constant pressure practically equal to the atmospheric. On the other hand, in the new Brown-Boveri boiler, the air and fuel are precompressed and the power required is recovered by expanding the exhaust gases from the boiler in a gas turbine.

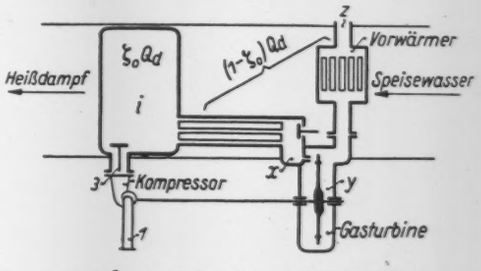


FIG. 1 SCHEME OF PRESSURE FIRING

(*Heissdampf* = live steam; *Vorwarmer* = preheater; *Speisewasser* = feedwater.)

A further increase of pressure of the gases can be obtained by combustion at constant volume. In this latter case, $L_{ve} = L_{ke}$ and $L_n = L_{de}$. Between the two limit conditions, there may be intermediate cases at which neither L_{ve} nor L_{de} is equal to L_{ke}.

It is claimed that the following equations cover all possible cases. Let W_0 denote the chemical energy of 1 kg of solid or liquid fuel, or 1 mol, or 1 nm³, of a gaseous fuel. W_0 here corresponds to the heat content at absolute zero which, according to Nusselt, gives the same value no matter whether combustion takes place at constant pressure or at constant volume. If the air for combustion has been supplied in a steady stream, which is possible structurally, one need consider only the heat content. If J_1 denotes the heat content of the initial materials of combustion at temperature T_1, J'_1 the heat content of the products of combustion at the same temperature, and H_{p1} the calorific value of the fuel at constant pressure and initial temperature T_1, then

$$H_{p1} = W_0 + J_1 - J'_1 \quad [4]$$

The products of combustion at the end of the process escape into the atmosphere with the temperature T_z and a heat content J_z (Fig. 1), it being understood that average values

are here referred to. To produce G_d kg of steam of heat content i_{1d} from feedwater with a heat content i_w, an amount of heat is required represented by the following equation:

$$Q_d = G_d (i_{1d} - i_w) \quad [5]$$

The energy equation of the gas turbine has the following general appearance

$$W_0 + J_1 + AL_{ki} = AL_{\varphi i} + Q_d + Q_v + J_z \quad [6]$$

Here L_{ki} represents the inner (indicated) work of the compressor, $L_{\varphi i}$ the inner work of the gas turbine, while Q_v comprises the incidental losses through radiation, conduction to the ambient medium, unconsumed fuel, etc. They may be taken to include also the work consumed by the auxiliaries, for example, the drive of the circulation pump. In the ordinary steam boiler, $L_{ki} = L_{\varphi i} = 0$. If the gas turbine is sufficient only to drive the compressor, and if by L_{km} and $L_{\varphi m}$ are represented the mechanical losses through friction in the bearings, etc., of the compressor and turbine, then

$$L_{\varphi i} = L_{ki} + L_{\varphi m} + L_{km} = L_{ki} + \Sigma L_m \quad [7]$$

From Equations [4] and [6] we obtain

$$H_{pi} + J'_1 = Q_d + A\Sigma L_m + Q_v + J_z \quad [8]$$

while the losses consist of the exhaust-gas losses

$$W_z = J_z - J'_1 \quad [9]$$

incidental losses Q_v, and mechanical losses ΣL_m. If these are added to the main exhaust losses, we obtain

$$W_v = J_z - J'_1 + A\Sigma L_m \quad [10]$$

Since the exhaust gases from the turbine are discharged directly into the atmosphere, it is desirable to consider the energy condition between the initial state 1 and the state x existing ahead of the gas turbine. If we designate the heat content of the gases at the entrance into the gas turbine by J_z, then

$$H_{p1} + J'_1 + AL_{ki} = J_z + \varphi Q_v + Q_d \quad [11]$$

The coefficient φ shows that not all the incidental losses occur up to the nozzle of the turbine. If this fact is neglected, then we can write $\varphi = 1$ and obtain the following expressions from Equations [11] and [8]:

$$W_v = J_z - (J'_1 + AL_{ki}) \quad [12]$$

If all the air of combustion, and in the case of gaseous fuel also the fuel gas, is compressed without cooling to the steam end pressure p_3, then the heat content J_3 at the end of compression will be constant, while a compression J^0_3 would be obtained with a compression free of all losses, so that

$$AL_{ki} = J_3 - J_1 \quad [13]$$

By inserting the values from [13] into Equation [12], we obtain

$$W_v = J_z - J_3 + J_1 - J'_1 \quad [14]$$

Where the compression is slight, W_v can, with sufficient approximation, be expressed by

$$W_v \leqq J_z - J'_3 \quad [14a]$$

where J'_3 denotes the heat content of the products of combustion at temperature T_3.

It would appear, therefore, that the loss through exhaust gases, to which are added the mechanical losses in the gas turbine and compressor, depend on the difference in heat content between the gases at temperature T_z of the turbine and at temperature T_3 at the end of the compression. If the temperature of the different particles ahead of the turbine is different, T_z and J_z must be considered as being average values only. If only a μth part of the gases of combustion is led through the gas turbine, while the rest is by-passed, and, for example, led through a separate preheater, and if the temperature of this remainder of the combustible gases at the time when they leave the preheater is T_v, then instead of Equation [12] the following holds good:

$$W_v = \mu J'_z + (1 - \mu) J_v - (J'_1 + AL_{ki}) \quad [12a]$$

As far as efficiency is concerned, this is determined by the loss in the exhaust gases ζ_a, expressed in terms of the heat content. The amount of heat liberated during combustion is somewhat different, depending on whether the combustion takes place at constant pressure or at constant volume. The temperature before combustion also effects a certain influence. Since, however, the fuel and the air of combustion are supplied in state J_1 and the utilization of heat is compared with that in some other boiler, it is recommended that the comparative loss in exhaust gases be put down as

$$\zeta_a = W_z / H_p \quad [15]$$

or the loss in exhaust gases plus the mechanical losses in turbine and compressor

$$\zeta_a = W_v / H_p \quad [15a]$$

using in all cases the upper heating value at constant pressure at temperature T_1.

As regards the temperature T_z and the corresponding heat content J_z, it is important to differentiate between the case where the exhaust gases from the turbine are discharged into the atmosphere and that in which a preheater is located beyond the turbine. In such a case as shown in Fig. 1, T_z means the temperature after the preheater. From Equations [8] and [10] it would appear that the internal efficiency of the gas turbine and compressor are not factors in this case, which means that the exhaust-gas losses, and hence the efficiency of the boiler, are entirely independent thereof. On the other hand, if the exhaust gases are discharged from the turbine into the atmosphere, then $T_z = T_y$ and depends on the efficiencies of the turbine and compressor.

If η_k is the effective efficiency of the compressor, which, as long as there is no cooling, may be derived from the adiabatic, L_{k0} the theoretical adiabatic work of compression, η_φ the effective efficiency of the gas turbine, and $L_{\varphi 0}$ the available work of the gas turbine, or that work which is obtained in the turbine by the expansion of the gases therein with no loss, then Equation [13] can be written as follows:

$$L_{\varphi 0}\, \eta_\varphi = \frac{L_{k0}}{\eta_k} \quad [16]$$

or, if we introduce the concept of "product of efficiency,"

$$\epsilon = \eta_\varphi\, \eta_k = L_{k0} / L_{\varphi 0} \quad [16a]$$

CONSTANT-PRESSURE PROCESS

In this process, essentially one combustion chamber only is required. The compression proceeds from 1 to 3 (see Fig. 2), while adiabatic compression would have proceeded from 1 to 3^0. By combustion at constant pressure p_3, a temperature T_f indicated by point f is attempted, but this temperature is not

actually reached because of dissociation and heat radiation to the pipes surrounding the combustion chamber. Heat is also given up through flow through the heating tubes. The state of the products of combustion ahead of the turbine is indicated by point x and beyond the turbine by point y, while y_0 indicates the state in a theoretical turbine free from losses. In order to obtain the desired effect, the velocities of the products of combustion p_x must be less than p_3, and if a preheater is placed

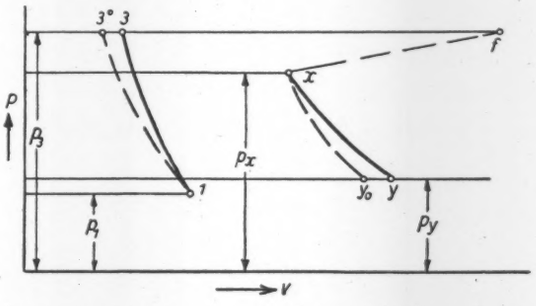


FIG. 2 p-v DIAGRAM OF THE CONSTANT-PRESSURE PROCESS

beyond the turbine, then p_y must be greater than p_1. The drop in pressure is taken care of in the simplest way by introducing a coefficient $\alpha > 1$, which gives

$$\alpha(p_x/p_y) = p_3/p_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots [17]$$

Since the theoretical work in the compressor $AL_{k0} = J_3^0 - J_1$, while the theoretical work of the turbine $AL_{t0} = J_x - J_y^0$, the "product of efficiency" is expressed by

$$\epsilon = \frac{J_3^0 - J_1}{J_x - J_y^0} \quad \ldots\ldots\ldots\ldots\ldots\ldots [18]$$

For example, if $p_1 = 1$ atm abs, $T_1 = 288$ K, $p_3 = 2.5$ atm abs, and if we set $\alpha = 1.5$, which is in accordance with experimental data given in *Zeitschrift des Vereines deutscher Ingenieure*, 1932, vol. 76, p. 1037, so that $p_x/p_y = 1.67$, then the values of Table 1 apply to the case of combustion of crude oil with 20 per cent excess of air.

TABLE 1

T_x	1000	900	800	700	600
T_y^0	852	790	703	614	526
ϵ	0.597	0.66	0.743	0.848	1

The higher the value of the product of efficiency ϵ, the lower the initial temperature T_x before the turbine. Because of this, it is advisable to try to attain high values of η_t and η_k. The temperature T_x corresponding to $\epsilon = 0.66$ is still quite high. It may be reduced by reducing α, which means that a lower drop in pressure is used to produce a given velocity of flow of gases of combustion, and it can also be done by raising somewhat the pressure p_3. It would appear, therefore, that $\epsilon = 0.66$ with pressure $p_3 = 3$ atm abs and $\alpha = 1.5$, $T_x = 820$ K. With $\alpha = 1.4$, $T_x = 750$ K, corresponding approximately to 470 C. A further rise in the value of p_3 produces no gain and merely increases the mechanical losses, and, hence, W_v. The theoretical temperature at the end of the expansion T_y^0, and hence the actual temperature at exit T_y, is so high that it pays to pass the gases coming out from the turbine through the preheater. If this latter is so proportioned that $T_x - T_1 = 100$ C, it will be found by calculation that the loss in exhaust gases ζ_a is 4.5 per cent for an excess of air of 20 per cent and ζ_a is 6.3 for an excess of air of 70 per cent.

EXPLOSION PROCESS

In the explosion or constant-volume process, a certain number of combustion chambers must be provided with means to utilize them alternately. On the other hand, compressors and gas turbines are eliminated. The first available information about this process created the impression that the greater part of the heat liberated in the process was immediately given up to the feedwater and superheater. From later information, however, it appears that a large amount of heat can be given up to the water only during the period of flow through the heating ducts. We are dealing here, therefore, with a series of events that cannot be represented by means of a simple cyclic process. Rather must we consider the change in the "quantity state." From the p-v diagram of Fig. 3 and T-s

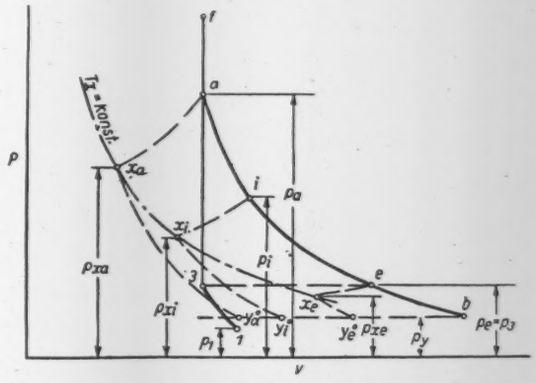


FIG. 3 p-v DIAGRAM OF THE CONSTANT-VOLUME PROCESS

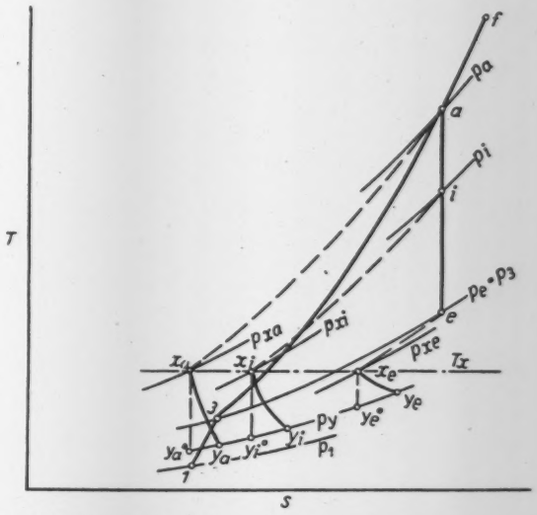


FIG. 4 T-s DIAGRAM OF THE CONSTANT-VOLUME PROCESS

diagram of Fig. 4, it is noted that each particle of gas emerging from the combustion chamber flowing through the heating ducts and then expanding in the gas turbine is subject to different changes of state. It is immaterial that such a presentation of the case is merely a simplification in so far as it applies to the T-s diagram, because of different constants of entropy of the materials of combustion and products of combustion. Curve 1 to 3 denotes the actual change of state during the compression; the exhaust occurring between 3 and f, while what has been said as to the constant-pressure process applies to T_f. As soon as the discharge valve leading to the turbine opens, the flow of products of combustion begins. The change

in the quantity states in the combustion chamber occurs, then, according to an isochor, while the change of state expressed in terms of unit of weight of the gases of combustion takes place with a loss of heat. Since this loss of heat to the contents of the chamber is at its maximum when it is given up to the heating duct surrounding the chamber at the maximum possible temperature, it can be calculated in advance, as a result of which the change of state during the emptying process $a \ldots i \ldots e \ldots$ may be considered as adiabatic lines. The pressure p_e very nearly coincides with the charging pressure p_3. The first gas particle coming out undergoes during this flow through the heating duct the change of state $a - x_a$, while the pressure falls from p_a to p_{za}. When the pressure in the chamber has dropped to some desired intermediate pressure p_i, the gas particle coming from the chamber undergoes during the flow through the heating ducts, a change of state $i - x_i$, while the pressure falls from p_i to p_{zi}. When the pressure p_e is reached, the entire remaining mass of gas is forced by the pressure of the air of combustion either through the turbine or through a separate preheater. In Figs. 3 and 4 it is assumed that all the states ahead of the turbine indicated by the broken lines x_a, x_i, and x_e correspond to a constant temperature T_z. Even if this assumption is not strictly fulfilled, it is fairly well approached, as the products of combustion in the heating ducts flow counter to the water being evaporated. As a result of this, J_z is a constant, and it is permissible to use Equation [11]. The available head in the gas turbine is different for each gas particle. For the first gas particle it corresponds to the adiabatic line x_a, y_a^0. For any given i, it corresponds to x_i, y_i^0, and for the rest of the gas x_e, y_e^0, but the end pressure p_u may have the same value for all gas particles. Because of losses in the turbine, however, the actual terminal states of the expansion are for the first gas particle y_a, for any gas particle y_i, and for the rest of the gas y_e. The efficiency of expansion for each individual gas particle is different because of the varying heat head.

If V_0 represents the volume of the combustion chamber, G_a the weight of the gases of combustion before they leave the chamber, then at the pressure p_i in the chamber there is retained a weight of gas G_i, while the rest of the gas G_t has passed through the turbine. Therefore

$$G_a - G_t = G_i = V_0/v_i \quad \ldots\ldots [19]$$

and

$$dG_t = dG_i \quad \ldots\ldots [19a]$$

The work in the turbine, expressed in kilogram-calories available up to the time the pressure p_e is reached, amounts to

$$AL'_{g0} = \int_{p_a}^{p_e} h_z dG_t = \int_{p_e}^{p_a} h_z dG_i = V_0 \int_{p_e}^{p_a} h_z d\frac{1}{v_i} \quad \ldots [20]$$

and to this must be added the further work

$$AL''_{g0} = h_e G_e \quad \ldots\ldots [21]$$

in the event the rest of the gases are led through the turbine. In Equation [20] v_i is the specific volume at the pressure p_i, and h_z is the available adiabatic heat head, the end value of which for the remainder of the gas amounts to h_e.

Incidentally, Equations [19] to [21] are strictly correct even if the changes of state in the combustion chamber do not occur in the exhaust of the gas therefrom according to an adiabatic curve but according to any polytropic curve. For purposes of integration, however, the assumption that the exhaust of gas from the combustion chamber is adiabatic brings about a much to be desired simplification. Moreover, as the expansion in the turbine occurs at low temperatures, we may, within that region, consider the specific heats as being constant, which permits us to write

$$h_z = ART_z \frac{k}{k-1}\left[1 - \left(\frac{p_u}{p_z}\right)^{\frac{k-1}{k}}\right] \quad \ldots\ldots [22]$$

wherein k is the exponent of the adiabatic curve of the products of combustion. The pressure drop required for the generation of the high gas velocities is taken care of by the introduction of a coefficient α, which may be assumed to remain constant during the entire process.

Let it be

$$\alpha \frac{p_u}{p_z} = \frac{p_i}{p_1} \quad \ldots\ldots [23]$$

By introducing the values from Equation [22] into Equation [20], one may determine in a very simple manner by graphic integration and by means of entropy tables the amount of work available. From Equation [22], it appears further that both L'_{g0} and L''_{g0} are proportional to the temperature T_z.

(Part I of an article by Prof. G. Zerkowitz, Munich, in *Die Wärme*, vol. 56, no. 16, April 22, 1933, pp. 243–249, 7 figs., *t*. The remainder will be abstracted in an early issue.)

LUBRICATION (See Engineering Materials: Oil-Permeable Metal Alloy)

MACHINE PARTS (See Foundry: Manufacture of Centrifugally Cast Piston Rings)

MACHINE-SHOP PRACTISE

Short-Period Rust Preventers

THIS article deals with materials for preventing rust on ferrous materials in storage, transit, and light handling. It should not be confused with making the materials resistant to corrosion.

Mineral oils may be used to prevent rust, but with their advantages, they suffer from having relatively poor film strength, which, among other things, prevents covering of angular edges. The thinner types tend to "ball up" and cause discontinuities in the film, which, added to their propensities for draining off, seriously limits their effective surface life. When the metal surface has been wet previous to coating, the moisture becomes entrapped beneath the oil film and rusting proceeds under the supposedly protected layer. Nevertheless, the use of mineral oils where short-period protection only is required, as in the passage of blanks from the press shop through the drill shop, is extensive because of the low cost and easy removal.

The same general remarks apply also to the use of petroleum jellies, with one or two exceptions. Method of application is the main disadvantage presented, either hot dipping and draining, or solvent solution, being necessary to provide a really continuous film. If applied by smearing with a cloth, however carefully performed, it is difficult, if not impossible, to eradicate uncovered cloth marks following the direction of motion.

Along these, rusting readily proceeds. Jellies of low consistency—and these are usually resorted to—have unduly poor film strength. On the other hand, the higher viscosity of the higher-melting-point products adds greatly to their adherence properties, and, correctly applied, this class provides valuable rust prevention. Furthermore, the incorporation of a very small percentage of suitable "fatty" oil—and even as low a percentage as 0.5 is effective—gives improved film strength to the lower-melting varieties.

As regards the use of varnishes, the author finds the cost of handling with good varnishes high, while the use of poor varnishes does not give satisfactory results. This particularly applies to cheap, quick-drying, spirit-gum varnishes. On the other hand, a well-chosen oil varnish of the type used for coating silicon-steel sheets for transformer lamination, will give excellent service and can be sprayed on in a relatively thin coat, or, where necessary, brushed on or dipped.

The author recommends particularly the use of lanoline, which is derived from wool fat. Not all forms of lanoline are suitable. The chief disadvantage of lanoline is that it is apt to have a very slight acidity which may promote corrosion of copper-bearing alloys. The other disadvantage is the softness of the film. On the other hand, however, the film is permanent and does not rupture with handling, drain off, or dry up. It is impervious to moisture under ordinary conditions. Lanoline forms emulsions with water, and, therefore, if applied to damp surfaces, emulsifies with the moisture present, as a result of which, continuity and adherence of film are not destroyed and rusting beneath the film is avoided.

In order to evaluate the relative merits of various types of preventer by rapid test, the author found that an ordinary type of hot humidity chamber proved invaluable. A simple form comprises a zinc-lined box with closely fitting glass lid. One hundred per cent humidity is attained by trays of water exposed in the bottom and uniformity of atmosphere by means of a small circulating fan. Temperature may be adjusted sufficiently closely by means of heating elements controlled externally from a rheostat. The test specimens can be conveniently suspended at the center of the chamber from horizontal rods at the top. All the media referred to were subjected to this hot-humidity test, the day temperature being 55 C, cooling to atmospheric at night being allowed in order to cause condensation of water drops on the samples. The results of a series of tests are given in the original article, while photographs showing the protection afforded by the most interesting media, applied to thoroughly clean, bright, mild-steel plates, and submitted to this test, are also reproduced.

The original article contains tables showing characteristics of the petroleum oils and jellies and durability under hot-humidity exposure of bright mild-steel plates coated after thorough cleaning. Some practical advice as to the application of rust preventers is given. Some pointers are the following: Varnishes should only be used on "show apparatus," or on parts to be heavily handled and where grease is forbidden. Medium-heavy oil may be reserved for the treatment of partly fabricated pieces; heavy oil or jelly should be utilized if long storage is anticipated. Even so, lanolines are considered justified in the latter case. Lanolines should be applied to all tools and to all precision-finished surfaces and mounted equipments. In short, in every case in which long-period rust protection is sought, and the monetary investment is of considerable magnitude, lanoline preventers demand prior claim. Their ease of application, service life, and protective qualities soon outweigh slight excess in initial material expenditure. (P. Mabb in *Machinery* (London), vol. 42, no. 1077, June 1, 1933, pp. 249–252, illustrated, *p*)

MEASURING INSTRUMENTS

Lunken High-Speed Diesel-Engine Indicator

POSSIBLY the greatest difficulty in designing a high-speed-engine indicator lies in the fact that the natural frequency of the indicator must be above the engine speed in order to avoid resonance, and it is stated that the frequency of the indicator should be about eight times that of the engine revolutions. Furthermore, the inertia of the reciprocating parts of the mechanism must be minimized as the inertia effect varies as the square of the speed. The Lunken indicator, made in England, is suitable for crankshaft speeds up to 2500 rpm. It is provided with a large-diameter piston having an area of 1 sq in. This piston has a short external compression spring which is so arranged that it may easily be changed. At this high speed, the maximum cylinder pressure which the instrument can record with this piston is 750 lb per sq in., while for pressures up to 1500 lb per sq in., at 2500 rpm, a piston having an area of half a square inch is used. An interchangeable liner is supplied with this in view. The motion work is of very light construction, provision having been made against undue wear of the fulcrums. The drum support can be swiveled in any desired direction for convenience of arranging the drum drive; the drum is driven by a steel ribbon.

The cylinder body and stopcock are in one piece so as to keep the clearances reasonably low and insure a rigid construction. Distinct from the indicator itself is the drum movement, which embodies a lever for controlling a starting and stopping device workable at any speed. The movement is driven direct from the engine crankshaft, camshaft, or any other convenient point. The adjustment of dead center of the connecting rod of the movement is effected by loosening the slotted nut which holds the crank disk, rotating the disk on the shaft, and retightening. The movement can be swiveled in any direction, to enable it to be in direct line with the drum without using guide rollers.

The diagram drawn by this new instrument measures $1^{7}/_{8}$ in. long by 1 in. deep, and is thus sufficiently large to planimeter satisfactorily. (*Gas and Oil Power*, vol. 28, no. 331, April, 1933, pp. 91–92, 1 fig., *d*)

METALLURGY

Creep and Structural Stability of Nickel-Chromium-Iron Alloys at 1600 F

A STUDY was made of the creep characteristics at 1600 F (870 C) of fifteen alloys covering a range from 1 to 75 per cent nickel and from 3 to 55 per cent chromium. The results were compared with those of a previous investigation at 1000 F (538 C) on similar alloys.

In the investigation at 1000 F (538 C) of the nickel-chromium-iron system, it was found that the alloys containing little or no iron, 50 to 80 per cent nickel, and 20 to 50 per cent chromium exhibited the greatest resistance to creep. At 1600 F (870 C), the strongest alloys are those containing approximately equal parts of nickel and chromium, and not more than 30 to 40 per cent iron.

As part of a metallographic study, the attempt was made to distinguish between the effect on structure of elevated temperature alone and of elevated temperature and stress combined. A comparison was made between the structure in specimens used in the creep test and that in the unstressed specimens of the same alloys annealed at 1600 F (870 C) for periods ranging from 100 to 1000 hr or quenched in iced brine from that temperature. In nearly all cases, the quenched specimens were

similar in structure to the annealed materials, which indicates that these alloys were not readily heat treated.

Carbide precipitation and agglomeration of the carbide at the grain boundaries were most pronounced in both the binary iron-chromium alloys and the ternary iron-chromium-nickel alloys of higher chromium content. Prolonged heating of both stressed and unstressed specimens, did not produce any pronounced changes in the structure of the binary iron-chromium alloys or the ternary alloys except those containing 50 per cent or more of nickel. (W. A. Tucker and S. E. Sinclair, *Bureau of Standards Journal of Research*, vol. 10, no. 6, June, 1933, pp. 851–862, 10 figs., 2 tables, *e*)

MOTOR-CAR ENGINEERING

The Mechanical Horse

THIS is a three-ton, articulated, five-wheel machine built by Scammell Lorries, Ltd., Watford, England. It is steered by a single front wheel and propelled by the two rear wheels of the tractive unit which is detachably coupled to a trailing unit. The most interesting features are the turntable and the coupling gear. Neither of the two can be described in detail.

Hinged to the turntable base behind the beam are the jockey-wheel legs. These, when lowered, are restrained from backward motion by a pair of stays, each composed of two parts hinged together and hinged at top and bottom. When the two parts are in line, the wheels are rigidly supported by a triangular structure. When it is desired to raise the wheels, the two-piece stays are pushed backward at the joint and thus, as it were, are caused to collapse, allowing the legs proper to swing back.

An ingenious locking device, released by the projecting member at the rear of the tractor, renders it impossible for the legs to collapse until extension rails on the tractor-frame longitudinals have taken the weight of the front of the trailer. The jockey wheels are lifted and lowered automatically as the two units are coupled and uncoupled respectively.

The front suspension and steering gear deserve notice. Incidentally, the original article states that the gasoline consumption is said to be 16 miles per gallon, the tax £25 or a little over $100, but the price is not mentioned. The mention of the tax would seem to indicate the importance which is attached to this matter in England. (*The Commercial Motor*, vol. 57, no. 1472, June 2, 1933, pp. 560–562, illustrated, *d*)

POWER-PLANT ENGINEERING

Sediment in Boilers as a Source of Danger

THE author claims that while the matter of scale deposits has received great attention on the part of power-plant engineers, that of sediment in boilers, closely allied with the formation of scale and constituting a grave source of danger of its own, has not received the attention that it deserves.

Softening of feedwater is usually produced by the addition of chemicals, or other forms of chemical treatment, sodium carbonate being extensively used for this purpose; and it is this that the author selects as an illustration of the mechanism of formation of one type of boiler mud, there being, however, many other types possible.

Fig. 5 shows diagrammatically the path of feedwater from its entry into the water softener to its delivery to the boiler. Sodium carbonate, Na_2CO_3, is in the water softener, where it combines with the calcium bicarbonate, $Ca(HCO_3)_2$, which is insoluble and produces a certain amount of mud. The complete chemical equation of this reaction is, as follows:

$$Ca(HCO_3)_2 + Na_2CO_3 = CaCO_3 + 2\,NaHCO_3$$

In addition, however, to calcium carbonate, which forms a muddy precipitate and can be easily kept out by filters, a bicarbonate of soda is formed which is soluble in the water, is not retained by either the filter or the water softener, and ultimately reaches the boiler. As no softener can do its work perfectly, from 3 to 4 per cent of hardness is left in the water, in addition to which the boiler contains bicarbonate of soda as well as some carbonate of soda due to the usual practice of putting a little too much of it into the water softener.

To start with, the feedwater has a temperature considerably below that of the water in the boiler. It goes therefore slowly toward the bottom of the boiler as indicated by the arrows in Fig. 5. During this descent, its temperature rises more and more, which ultimately causes the precipitation of the remainder of the hardness salts held in the water.

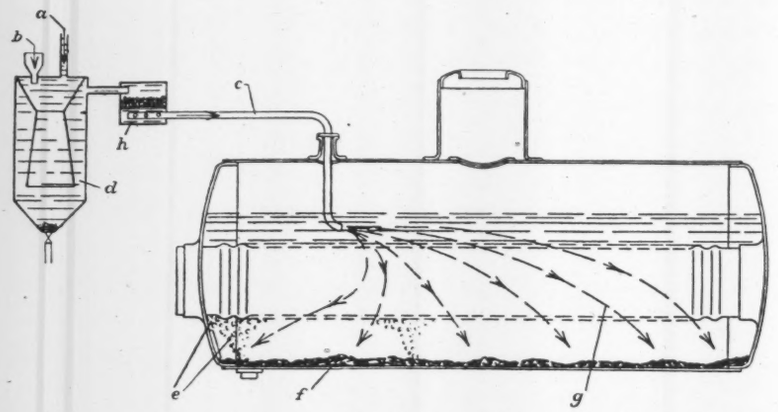


FIG. 5 DIAGRAMMATIC SECTION OF A BOILER SHOWING FORMATION OF SEDIMENT

(*a*, raw water; *b*, carbonate of soda; *c*, softened feedwater containing from 3 to 4 per cent of hardness and holding in solution an excess of carbonate of soda and some bicarbonate of soda; *d*, water softener; *e*, tiny bubbles of anhydrous carbon dioxide escaping from the upper layers of sediment, and adhering to the lower part of furnace tubes, the line rivets, etc.; *f*, in the mud containing carbonate and bicarbonate of soda there form, by hydrolysis, caustic soda and bubbles of anhydrous carbon dioxide capable of attacking the boiler; *g*, relatively cold feedwater goes to the bottom and at the same time carries with it carbonate and bicarbonate of soda in solution; *h*, filter.)

In addition to its being due to the thermal effect, this precipitation is accelerated by the combination of the hardness-forming salts with the excess of carbonate of soda brought over from the water softener. The results of this combination likewise go to increase the amount of sediment which then consists chiefly of calcium carbonate, $CaCO_3$. Attention has been called, however, to the fact that the feedwater also contains bicarbonate of soda, and this latter decomposes under the hydrolyzing action of the pressure and temperature, this decomposition occurring in accordance with the following chemical formula:

$$2NaHCO_3 = Na_2CO_3 + H_2O + CO_2$$

Under the action of this hydrolysis, sodium carbonate,

Na_2CO_3, and anhydrous carbon dioxide, CO_2, are formed. The CO_2 is deposited when in the nascent state in the form of tiny globules which attach themselves to the infinitely small particles of the muddy precipitate and sink with them through the water mass, finding ultimate refuge at the bottom of the boiler. The decomposition of bicarbonate of soda, however, takes place very slowly, with the result that the sediment at the bottom of the boiler always contains a certain amount of undecomposed bicarbonate. In other words, the process of decomposition continues within the mass of sediment. This is important, because the globules of anhydrous carbon dioxide formed within the sediment cannot escape from it, because of the growing thickness of the layer of sediment.

It has been shown in the previous discussion that the decomposition of the bicarbonate of soda results in the formation of a carbonate of soda. This is held in solution in the mud and is decomposed by hydrolysis, the velocity of the decomposition depending on the pressure obtaining in the boiler. The mechanism of this decomposition is shown by the equation

$$Na_2CO_3 + H_2O = 2NaOH + CO_2$$

This results in the formation of caustic soda and anhydrous carbon dioxide. Since all of these reactions take place within the sediment, the latter becomes ultimately tremendously rich in caustic soda and anhydrous carbon dioxide.

The corrosive effects of caustic soda on both copper and iron are very well known, which is not exactly the case with carbon dioxide, which, however, is endowed with an extremely great capacity to attack iron, particularly where, being protected by the sediment, it can carry on its pernicious activities undisturbed. The protection of the mud lies in the fact that it prevents circulation of water in contact with the surface of the boiler plates and thus prevents the globules of carbon dioxide adhering thereto from being washed away. Moreover, recent researches have indicated that carbon dioxide is capable of powerfully attacking iron, even where atmospheric air is completely absent, which is the case, for example, with boiling water. When this happens, a spongy growth is formed on the iron consisting of sesquioxide of iron, Fe_2O_3, or simple rust.

The author claims that extensive evidence of corrosion in the lower part of the furnace tubes, along the line of the rivets, and at the junction of the tubes with the front end of the bottom of the boiler are all due exclusively to the action of anhydrous carbon dioxide escaping from the upper layers of sediment. The author calls attention to the fact that many of the scale removers generally introduced directly into the boiler contain certain percentages of sodium carbonate. He then makes a brief reference to the Permutit process and says that carbon dioxide may form where raw water is used through the decomposition by heat of calcium bicarbonate present therein. Moreover, feedwater may contain magnesium chloride, which decomposes by hydrolysis into magnesium oxide and hydrochloric acid, the presence of the latter materially increasing the other corrosive effects. He cites an analysis of a boiler sediment as published in 1931 by G. Schmidt in *Die Wärme*, p. 405, and calls special attention to the presence of 12.28 per cent of iron rust. The content of iron rust in the feedwater was very much less, which would indicate that the corrosive effect of anhydrous carbon dioxide has already made itself felt.

The author calls attention to the mechanical effects of sediment, for example, the possibility of clogging water glasses. As to remedies, he recommends blowing off at frequent intervals from one to two hours, claiming that with such frequent blow-off, the quantities to be removed are small and the operation should take only a very short time. If such short and frequent blow-off is resorted to, the apparatus must be such as to close perfectly and yet be easy to handle. (H. Richter in *Revue Universelle des Mines, de la Metallurgie des Travaux Publics*, series 8, vol. 9, no. 6, Mar. 15, 1933, pp. 157–161, 2 figs., p. Compare an article on "Boiler Sludge as a Source of Danger," by Hans Richter, abstracted in MECHANICAL ENGINEERING, vol. 54, no. 8, Aug., 1932, pp. 576–577)

PUMPS

Hydraulic Characteristics of Pump Blades

IN PROGRESSIVELY developing the profile of the wheels of screw pumps while at the same time increasing the specific speeds, one comes finally to the pure axial pump with the kind of blades shown in the original article. In consequence of the great speed and in order to reduce the resistance and obtain high efficiencies, it is necessary to keep the surface of the blades as small as possible and choose the exact profile with great care.

The two examples in Fig. 6 show to what degree the resistance depends on the profile. These are both symmetrical profiles, the resistances of which have been measured in the aerodynamic testing laboratory at Göttingen. In the case of the uniform thin plate rounded at the edges, the resistance to motion is about 2.3 times greater than in the one with streamline profiles, while the frictional resistance is the same in both cases.

FIG. 6 TOTAL RESISTANCE W OF TWO SYMMETRICAL PROFILES OF PUMP BLADES

The deflection of individual lines of flow of the stream by the propeller blades is comparatively slight, except that it increases in proximity to the blades. Above the propeller, the average velocity is again established and each liquid particle has about the same quantity of energy.

What happens when a fluid in motion is submitted to small deflections has been made the subject of particular study in aerodynamics, and the theories of the behavior of airplane wings have been confirmed by numerous experiments. As long as the question of cavitation does not arise, the results obtained with air can be applied at once to liquids, consideration being taken of Reynolds' law of similarity. As a specially important result of such investigations, it was shown that if the deflections and the speed exceed a certain amount, dissociation takes place. This has a very unfavorable effect on the efficiency and on the lift of the pumps. It is therefore necessary to make careful calculations and investigations and also to carry out thorough tests, in order to find the most suitable profiles for particular cases and the limits within which they may be adopted. Details concerning the new methods of calculating and constructing are not given. By introducing new definitions, as, for example, that of circulation, the new methods resemble to a large extent the methods used for studying electric phenomena. For example, the mathematical expressions for electromagnetic lines of force are very similar to those for hydraulic lines of flow.

No definite rules can be laid down for the correct type of propeller pump to choose. In general, the open type of pump is chosen for delivering very large quantities of water against a low head, while the closed arrangement is used for high heads and when delivering into a delivery main. In both cases, the

motors for driving the pumps are installed above them in a special room and connected to them by a shaft.

With propeller pumps, it is absolutely essential to fit a non-return valve in the delivery pipe, but a gate valve required for centrifugal pumps is generally unnecessary. In order to prevent the motor from being overloaded, propeller pumps must always be started with the delivery gate valve open. Several irrigation and drainage plants employing this kind of pump are described in the original article. (Spr. in *Sulzer Technical Review*, no. 1, 1933, pp. 10–16, illustrated, *d*. Compare with the article dealing with the Sulzer pumps including test results of a screw pump in *Mechanical World*, vol. 93, no. 2420, May 19, 1933, pp. 485–487)

RAILROAD ENGINEERING

French Mountain-Type Locomotive

THIS mountain-type locomotive has been introduced for the service between Paris and Cherbourg, which it is proposed to reduce to 4 hr with 600-ton trains. Features of particular interest of this engine are the adoption of three high-pressure cylinders with poppet distributing valves and the use of an automatic stoker on a comparatively small grate (54 sq ft). The boiler has nearly 4000 sq ft of heating surface and a superheater surface of about 920 sq ft, the working pressure being 285 lb per sq in. All the cylinders are of approximately the same capacity.

The crankpins are arranged at 120 deg to each other, but the crank for the inside cylinder is on the leading driving axle, while the pins for the outside cylinders are on the second axle.

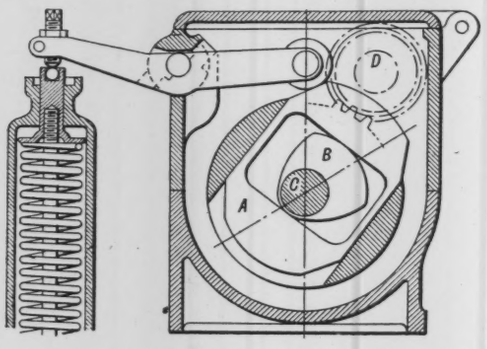


FIG. 7 RENAUD VALVE GEAR OF FRENCH MOUNTAIN-TYPE LOCOMOTIVE

The connecting rod between the second and third axles on the off side is in the form of a hinged triangle, the apex of which drives a crank on a short horizontal shaft, which operates the Renaud valve gear, through a second shaft running forward, to which it is coupled by bevel gearing. The mechanism of the valve gear itself is indicated by Fig. 7. All the valves are closed by springs and opened by short levers moved by cams. The camshaft, which is rotated by the mechanism just mentioned, is slotted to receive the cam members *A*. In each of these members there is a rectangular opening which accommodates a triangular cam *B* fast on a shaft *C*, which does not rotate with the camshaft. It can, however, be moved through part of a circle by the control shaft *D* and the gearing indicated. Thus, by altering the position of the triangular cam *B*, the sequence of events in the cylinder may be modified.

In the stoker, the coal is transferred from a trap in the tender by a worm, rotated by a small steam engine, to a vertical open-topped chamber in the firebox just under the door. The coal rises in the chamber, and, as it reaches the rim, is blown over the grate by steam jets. The firebox is of copper, with a combustion chamber projecting into the barrel of the boiler, giving it a maximum length of 12 ft 9 in. The superheater has 30 elements. The tender is carried on roller bearings and the tank is of welded construction. The total weight of engine and tender, loaded, is 206 tons. (*The Engineer*, vol. 155, no. 4036, May 19, 1933, p. 507, 3 figs., *d*)

Cyclone Front End on Locomotives

THIS device was originally developed on the Northern Pacific in order to permit the burning of sub-bituminous coals of the Rosebud variety without spark emission. It consists essentially of a sheet-metal drum equipped with breaker strips around the interior circumference and deflecting vanes at the intake so arranged that exhaust gases are given a centrifugal motion which delays the cinders in the drum long enough for them to be reduced in size and extinguished before being discharged to the atmosphere. No netting or similar restriction to draft is required with this construction.

The general arrangement of the latest (Type C) front end is shown in the original article. It surrounds the inside stack extension and is used in connection with the low, straight, exhaust base with the intake to the drum placed directly in front of the flue sheet. A vertical baffle plate, surrounding the opening into the drum, shuts off from the draft area all of the smokebox, from the superheater header forward. This arrangement excludes all steam pipes and joints, with the exception of the superheater units, from the draft area and therefore minimizes the possibility that steam leaks or outside air leaks around the door ring and steam pipes will interfere with the draft.

Extensive tests were carried out with the conventional Master Mechanics front-end arrangement and with the Cyclone Type-C design on the Soo Line. With 29 per cent cut-off at the foot of the hill, the Cyclone-equipped locomotive at a speed of 47 mph developed $6^1/_2$ lb back pressure. To maintain speed on the hill, the cut-off was increased to 34 per cent and again to 39 per cent, the speed remaining constant to this point. As the increasing grade reduced the train speed, the cut-off was increased at intervals from 53 to 71 per cent at the top of the grade where the speed was 24 mph. During this time, the back pressure remained practically constant at 8.2 lb, showing that the locomotive had a reserve power capacity which could have been used, if necessary.

Under the same grade and operating conditions, the locomotive with the Master Mechanics' front end developed a speed of 39 mph with a cut-off of 29 per cent and a back pressure of $7^1/_2$ lb at the foot of the grade. In an effort to maintain this speed on the grade, the cut-off was increased to 34 per cent, bringing the back pressure up to 10 lb, the speed falling slightly, however, to 38 mph. As the speed continued to decrease, the cut-off was increased at intervals until, at 53 per cent, a maximum back pressure of 13.4 lb was developed at a speed of 22 mph. From this point on, both the speed and back pressure dropped rapidly as the cut-off was further increased to 67 per cent at the top of the grade when the back pressure was 12 lb and the speed 16 mph. While the tractive force of the locomotive during this test continued to increase until the top of the grade was reached, the maximum horsepower was developed before reaching the top. It is claimed that with the Cyclone front end certain advantages can be attained, such as better steaming, reduced fuel consumption, sparkless operation, and increased hauling capacity. (*Railway Age*, vol. 94, no. 20, May 20, 1933, pp. 723–725, illustrated, *de*)

REFRIGERATION

The Thermodynamic Properties of Dichloromethane

THIS material (CH_2Cl_2) is extensively used in Japan as a refrigerant. The authors determined its thermodynamic properties, expressed in the original article in the form of three tables, and also constructed a pressure-enthalpy diagram. They have also derived the characteristic equation for this material as well as equations for enthalpy and entropy for various conditions. The latent heat of evaporation, the enthalpy and entropy of saturated liquid dichloromethane, and some other quantities have been calculated for various temperatures.

The numerical values thus calculated are collected in two tables. The first table gives values of saturation pressure, specific volume, specific weight, enthalpy, and entropy of both saturated liquid and dry saturated vapor, and also the values of latent heat of evaporation, increase of entropy due to evaporation, and pressure increment along the saturation line in accordance with the temperature as a basis. The second table gives values of specific volume, enthalpy, and entropy of superheated vapor up to the temperature of 100 C, and also those of dry saturated vapor under the pressure from 0.04 kg per sq cm to 1.4 kg per sq cm. (Sugao Sugawara and Isamu Yosigi, in *Journal of the Society of Mechanical Engineers*, Japan, vol. 36, no. 192, April, 1933, pp. 225 to 230, in Japanese, with a brief abstract and tables in English, pp. S17 to S20, *e*)

SPECIAL PROCESSES (See Foundry: Die-Casting Iron and Steel)

STEAM ENGINEERING

The Belliss-Morcom Midget Turbine

THE BELLIS-MORCOM CO., in cooperation with Higgs Motors, both English concerns, developed a midget turbo-generator for small power requirements where steam is available but not an electric supply. The set is capable of developing 4 kw at 4000 rpm with steam at 150 lb per sq in. The turbine is of the two-pass, velocity-stage, impulse type in which the steam is practically entirely expanded in a single nozzle. The wheel is fitted with blades arranged for radial flow. The steam escaping from the nozzle is directed on to the outer periphery of the ring of blades, leaving it on the inner periphery. From there it is redirected to the blades by a guide passage in the cover, finally emerging on the outside once more, and then to the exhaust branch. It is said that a self-contained condensing unit or a vertical unit can be supplied. The overall dimensions of the condenser unit are 39 in. in length by $28^1/_4$ in. in height. (*The Power Engineer*, vol. 28, no. 327, June, 1933, p. 225, 1 fig., *d*)

TESTING AND MEASUREMENTS (See also Fuels and Firing: Correlation Between Calorific Value and Density of Fuel Oils)

A Method for Rating the Grindability or Pulverizability of Coal

THIS describes a method developed by the Fuel Research Laboratories, Department of Mines, Canada, correlated with the Cross and Hardgrove methods. The purpose of the investigation has been to select or devise a laboratory method for deducing an index which would show the comparative grindability or pulverizability of coals. An important requirement of such an index is that it must be capable of interpretation into terms of mill capacity. The intention was to make it possible to predict the approximate amount of coal, say, in tons per hour, that can be pulverized to a stated fineness in a given mill, knowing the general relation existing between the "index" in the laboratory and mill capacity. The three methods for determining grindability indexes (including the Cross and Hardgrove methods) are described in detail and compared. Brief references are made to other work along this line, and a graphic description of the present method is given.

No very definite relationship has been shown between calorific values or rank, and fineness of, or power requirements for, pulverization beyond a general trend toward increased fineness and decreased power as calorific values and rank increase.

If, however, the fineness as given by the percentage through either the 100- or 200-mesh sieve for the individual tests on each fuel is plotted against the corresponding power requirements, a curve will be obtained for each fuel. From these curves, a value may be secured in respect to fineness at one power rate, that is, the average power rate for all tests on all fuels, and such arrangement is shown in the original (Table III) to approximate closely to a similar arrangement of the fuels in respect to increasing grindability index numbers. This is the only correlation that can be made at the present time with the information at hand between grindability ratings given by the laboratory method and results obtained in a commercial pulverizer.

An appendix contains a recommended procedure for rating the grindability of coals in all three methods. (C. E. Baltzer and H. P. Hudson, Mines Branch, Canada Department of Mines, Advance Section of Investigations of Fuels and Fuel Testing, 1932, published in 1933, no. 737–1, *p*)

TEXTILES

"Shirlacrol"

THIS is a new phenolic wetting agent for which a high degree of efficiency in mercerizing is claimed. For mercerizing purposes, caustic-soda solutions of 22 to 26 per cent concentration by weight are used. When this treatment is applied to unbleached cotton, the slow and irregular penetration of the material by the alkali leads subsequently to uneven dyeing and to other irregularities in the finishing processes.

During recent years, many wetting adjuvants have been introduced to assist rapid and uniform action by the caustic lye. These wetting agents should be stable in the strongly alkaline medium used. Furthermore, a clear solution is desirable, since in practise mercerization is often intermittent and undissolved materials tend to deposit out when the solution is not in use.

Investigations made at the Chemical Research Laboratory, Teddington, England, in cooperation with the British Cotton Industries Research Association, have shown that a wetting material can be developed from certain fractions of tar acids from vertical-retort and low-temperature tars. The optimum preparation has been named "Shirlacrol" and important claims are made for it. The crude tar acids have to be freed from neutral and basic impurities and from small amounts of constituents which, by producing deep red solutions in alkaline media, tend to stain vegetable fibers. These impurities are removed effectively by the combined action of air and steam introduced into a boiling solution of the crude tar acids in caustic soda. In industrial practise, this derivation might be more economically applied directly to the alkaline extracts normally obtained by tar distillers in the isolation of tar acids. Some details of manufacture are given in the original article, where it is stated that commercial "Shirlacrol" consists of a fraction of tar acids

distilling between 210 and 270 C and containing on an average 55 to 60 per cent of its volume distilling below 230 C. Different grades of "Shirlacrol" suitable for use in caustic-soda solution of any given concentration can be obtained by graded fractionation.

The wetting power, which in mercerizing lyes is greater than that of any known preparation, is a characteristic inherent in the fractions themselves, which therefore require no added component to develop this useful property. Furthermore, they do not require the addition of stabilizing components, since with caustic alkali they produce solutions which do not deteriorate in wetting efficacy. "Shirlacrol," which is practically inodorous, is less corrosive and less toxic than preparations containing carbolic or cresylic acids, and when dissolved in alkalies of appropriate concentration, it yields a clear, stable, and almost colorless solution.

Since the introduction of vertical-retort tars, the chief outlet for high-boiling tar acids has been the preparation of disinfectant fluids such as sheep dips, for these higher phenols are also powerful germicides. Unfortunately, in recent years this market has been severely restricted, while the production of these tar acids has steadily increased. In addition, the possible expansion of low-temperature carbonization would add still further to the output of higher phenols, and this increased production would render the problem of the disposal of such phenols increasingly urgent. Since the cotton industry is capable of consuming, with advantage, large quantities of an efficient wetting agent produced at an economic price, it is evident that the exploitation of "Shirlacrol" would be of mutual benefit to the tar-distilling and textile industries. (Gilbert T. Morgan, D. D. Pratt, and A. E. J. Pettet, in *The Dyer*, vol. 69, no. 11, May 26, 1933, pp. 549–550, illustrated, *d*)

THERMODYNAMICS

The Transmission of Heat Through Fabrics

THE purpose of the research reported in this paper was to determine the effect of air permeability and of perforations in fabrics on their thermal insulating properties. The results obtained are expressed in terms of thermal insulating value (T.I.V.), that is, the percentage of reduction of heat flow caused by the fabric under the specific test conditions. For all fabrics, the air permeability and the percentage of hole area (light transmission) were determined.

The thermal insulating values when plotted against thickness presented a series of points which were found to lie in a band on either side of a straight line which did not pass through the origin (Fig. 8). It was suggested that the deviation of the band from the mean line is due to the differences in air permeability and light transmission, which allow different amounts of air and of radiant heat to pass through the fabrics. Throughout the tests, hygroscopic equilibrium was estimated so that no heat is supposed to have been transferred by evaporation at the warmer and by condensation at the cooler places.

From the results, it appeared to be possible to assign to each group of fabrics a mean excess heat flow above the average, and curves for excess heat flow against air permeability and hole area were plotted.

An investigation of the flow of heat by convection through fabrics involved a determination of the general form of the air current through the fabric, and the apparatus and the method used are described.

In the discussion, J. H. Awbery, who himself has carried on investigations in heat conduction, comments on what is known about the thermal insulating value as a function of permeability after correction for radiation effects. This portion, and the author's reply, cannot be abstracted because of lack of space. It has been found that there is a heat interchange between the convection currents and the fabric, which is important in considering the flow of heat through such insulators. (M. C. Marsh, Wool Industries Research Association, Leeds, *The Proceedings of the Physical Society*, vol. 45, pt. 3, no. 248, May 1, 1933, pp. 414–424, 5 figs., *e*)

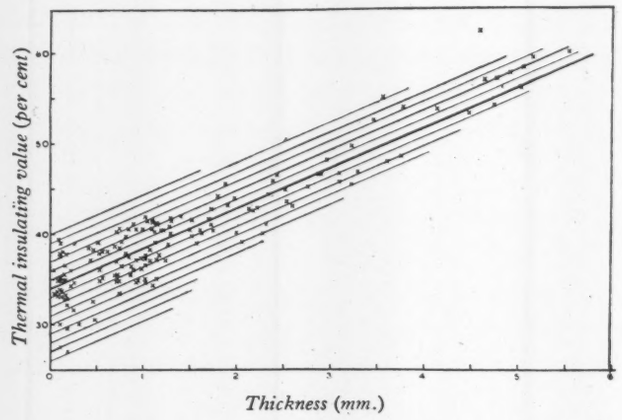


FIG. 8 THERMAL INSULATING VALUES OF FABRICS PLOTTED AGAINST THE THICKNESS

VARIA

Labor-Saving Machinery in the New Deal

THE point has been made that if prices are fixed, manufacturers have only two ways to increase their profits: through increased volume and through lower costs. Since wages will be fixed, there will be no opportunity for lower costs through cuts in labor rates. Inasmuch as the object of the NRA is to increase employment, it has been asked whether a manufacturer is at liberty to introduce labor-saving machinery which, through lower costs, displaces workmen.

General Johnson's position on this point, and it has been the object of criticisms, appears to be toward discouraging further use of labor-saving devices. He made this declaration in connection with his statement, that he is going to ask "something in the nature of an armistice on increased producing capacity, until we see if we can get this upward spiral (purchasing power) started."

He said that no hard and fast rule can be made, but added that "we are going to plead very earnestly with these industries not to use any further labor-saving devices or anything to further increase production."

Sponsors of the Act have declared that it not only would increase competition, but that it also would encourage research, invention, and technological development generally. General Johnson's position appears to be directly in conflict with this view, though he indicated plainly that he would seek only a temporary halt in withholding further use of labor-saving devices. But even so, it has been urged, it is an encouraging prospect for replacing obsolete equipment with modern metal-working machinery and other improved units of production, and it is this very field which is a prospective source of large buying and therefore of increased employment and wages, all of which would evidently aid in lifting purchasing power. (From a report by L. W. Moffett, Resident Washington Editor, *The Iron Age*, vol. 131, no. 26, June 29, 1933, pp. 1047–1049, *g*)

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AERONAUTICS

Progress in Aeronautical Engineering. This report, contributed by the A.S.M.E. Aeronautic Division, reviews the progress made in the field of aviation during 1932. It deals successively with military aeronautics, naval aviation, air transport, airports and air navigation, airships, airplane design and construction, aircraft-engine developments, and aerodynamics. (Paper No. AER-55-1.)

Lightning Investigation as Applied to the Airplane. The hazard to aircraft from lightning is very small, but has received much attention. Lightning itself has caused but few fatalities, and many cases of trouble have been unjustly charged to it. Once the effect of lightning upon the pilot or plane is recognized, steps can be taken to reduce the hazard materially, if not to eliminate it. Some interesting information has been gathered from tests as to protection for free balloons, planes, and other equipment. (Paper No. AER-55-2, by A. O. Austin.)

Photogrammetric Measurement of Airplane Landing Speeds. The paper gives a method of airplane landing-speed measurements. Wing loadings have mounted steadily in the past few years, with consequent increase in landing speed. Within the past two years wing areas have been so ruthlessly clipped that some of the 1932 models of conventional commercial airplanes are carrying weight per unit of wing area far in excess of the fastest wartime pursuit airplanes. To fit the government requirement of 65 mph as the limit for passenger-airplane landing with full load in still air, several manufacturers of stock models are assisting in the development of a method of actual measurement of landing speeds. The photogrammetric method gives an accurate and permanent record. (Paper No. AER-55-3, by V. C. Finch.)

Pressure in Airships. The use of pressure in the so-called "pressure airships" and the methods used for maintenance of pressure are described. The effects of "gas head" and of excess internal pressures are considered as design factors, showing the advantages derived from a strength standpoint. It is pointed out that, by utilizing the pressure, the low factors of safety used by airship designers for critical loading conditions can be eliminated. The ultimate design of the pressure rigid airship is discussed. Recognizing the disadvantages of manual control of pressure employed in the present airships, it is emphasized that pressure control can be made perfectly automatic if pressure regulators used in the modern power-plant installations are adopted for airship-pressure control. The proposed pressure-control system for large metalclad airships is described. To utilize the advantages of pressure as a design factor, the materials used in the present rigid airships should be more efficiently disposed around the cross-section, again pointing to ultimate metalclad design. (Paper No. AER-55-4, by W. A. Klikoff.)

Air Compression With Temperatures Above Adiabatic, With Special Reference to Airplane Superchargers. In compressing air or other gases by means of reciprocating or centrifugal compressors of comparatively large size, with large cooling areas and often water-jacketed, an appreciable amount of heat is removed which helps to decrease the power input. This cooling, however, is by no means essential, and under many circumstances decrease of power for compression by cooling is not very great. Furthermore, conditions are often encountered which make cooling inadvisable. In the present paper the author outlines the mathematical theory to be used when due consideration of all of the circumstances indicates that a compressor with a small amount of cooling is the most advantageous. (Paper No. AER-55-5, by S. A. Moss.)

The Mooring and Ground Handling of a Rigid Airship. Problems in mooring and handling rigid airships are treated. Differences of opinion resulting from the relatively limited airship operating experience are discussed. Prediction is made that successful mooring and handling of rigid airships will center around the low mast. When the problems of airship terminals reach a satisfactory status, as it is asserted they soon will, it will be found that extremely important contributions will have been made by the airship personnel and engineering talent of the United States. (Paper No. AER-55-6, by C. E. Rosendahl.)

APPLIED MECHANICS

Progress in Applied Mechanics. This report, contributed by the A.S.M.E. Applied Mechanics Division, covers such subjects as the theory of elasticity and stress analysis, compiled by Dr. S. Timoshenko; rigid dynamics, by J. P. Den Hartog; mechanics of materials, by R. E. Peterson; hydrodynamics and aerodynamics, by O. G. Tietjens; lubrication, by G. B. Karelitz and L. M. Tichvinsky; and thermodynamics, by John A. Goff. Over sixty references are given. (Paper No. APM-55-1.)

MACHINE-SHOP PRACTICE

Machine-Design Management. Extended search reveals many papers on drawing-room detail, routines, printed forms used in drafting rooms, drafting-room "kinks," etc., but almost nothing relating to the broader problems of management which the design supervisor and his superiors must face. The present paper is a discussion of design-management practises, and is an attempt to record such of these practises as concern the Hawthorne Machine-Design Division of the Western Electric Company, Inc. The author's views are influenced largely by the past and present problems confronting him. Many of these, doubtless, are peculiar to the Western Electric Company. (Paper No. MSP-54-9, by J. L. Alden.)

Oxygen Machine Cutting in Great Britain. Cutting of metal by the oxygen flame has been practised commercially for more than 25 years by means of hand-guided blowpipes. The hand cutter is largely used for scrap cutting and by concerns whose work involves the use or manipulation of steel plate, forgings, or sections. The work produced by the hand cutter is rough and inaccurate. The paper describes the use of the machine designed to hold the cutter rigidly and that propels the cutter by a simple feed motion at a uniform speed. Great progress has been made in the past 10 years in the development of these machines, and they now are considered as reliable, quick, and accurate shop tools. The paper describes the various machines and their uses, and gives instances of their application to difficult

work, with the resulting reduction in costs. (Paper No. MSP-54-10, by C. G. Bainbridge.)

Researches on Steels and Forgings for Greater Density, Machinability, and Durability. In this paper the authors give details of a research carried out in an endeavor to find means of improving the machinability of gear blanks upset from bar steel, as well as the durability of the finished gears after heat treatment. The investigation shows that a steel of coarse grain upsets into a denser product than one of finer grain, and that this denser material is more readily machined, and with much less resultant tool wear. Specifications are given for the steel finally adopted and also details of its heat treatment, as well as figures from dynamometer tests which indicate a longer life for the wearing surfaces of the teeth on the gears made therefrom, and a marked decrease in pitting and granulation. (Paper No. MSP-54-11, by F. W. Cederleaf and W. E. Sanders.)

Life of Tools Machining Free-Cutting Brass. The authors present a considerable amount of data on the life of tools under shop conditions machining free-cutting brass in automatic screw machines. The analysis of this data shows that larger feeds and higher cutting speeds than those used in current practise can be combined with a reasonable tool life. The type of relation existing between cutting speed, feed, and life of tool found by Frederick W. Taylor and others for rough-turning of steel does not fit these tests of forming and drilling free-cutting brass. Within the limits of these tests an increase of the cutting speed is accompanied by greater economy. When machining free-cutting brass with ground circular-form tools, the life of the cutting tool between grinds appears to be nearly independent of the feed and of the cutting speed, and to depend primarily on the linear distance the work moves in contact with the tool. This indicates that the wear is primarily a lapping action, which is influenced more by the amount of movement of the edge of the tool against the work than by the pressure between them. Within the limits of the tests the maximum economy in machining free-cutting brass is secured by using the largest feed that the work and tools will stand and by running the stock at the highest spindle speed available. (Paper No. MSP-54-12, by L. D. Spence and J. A. Hall.)

Special Steels for Castings. During the past 15 years there have been many developments, in chemical composition and in heat treatment, for the manufacture of steel castings. During the last 10 or 12 years there have been installed many electric furnaces admirably adapted for the production of special steels for castings. A huge task assumed by the steel-casting industry has been to determine by actual experiment what properties result from combinations reasonable to consider from the standpoints of first cost and economical service. The paper treats of the diversified properties developed by heat treatment, of the varieties of alloy cast steels, and of the characteristics of special steels for castings. The industry is free to employ countless combinations of potentially useful elements that, after proper heat treatments, will provide desirable properties in the steel castings. (Paper by R. A. Bull.)

Influence of Oil Compressibility on Speed Characteristics of Hydraulic High-Speed Presses. Industry provides new fields for the application of hydraulic pressure. The newer types of hydraulic presses permit much higher operating speeds, and their use in production work has been made possible. The designer is confronted with the problem of determining the maximum speed obtainable with a given set of conditions. The compressibility of the pressing fluid plays a large part in this problem. Formulas are derived for lag caused by the time required to build up pressure in press cylinders for both constant- and variable-delivery pumps, and an investigation is made of the time lag due to pressure release in the cylinder. (Paper by Walter Ernst.)

Design of Product to Utilize Die Casting Instead of Machine Parts. Die casting as a process for making intricate metal parts and complete articles has progressed rapidly in recent years. The alloys used in modern die-casting practise are classified in five main groups—those with bases of tin, lead, zinc, and aluminum, and the copper-base alloys in which the brasses and copper bronze are alloyed with zinc, tin, lead, aluminum, nickel, manganese, etc. The differing properties of these alloys are described by the author as indicating their use in die casting. The machines and the methods used in die casting are described, and the resulting life of the steel dies is given. Comparison of the relative costs of die castings and machined parts indicates the many preferred uses for the former. The artistic possibilities attainable without greatly increased cost in die castings are indicated. (Paper by Louis H. Morin.)

TEXTILES

Variable-Speed Spinning. This paper deals with the application of variable-speed control to textile machinery. Tests made thus far have been on cotton yarn, but the author believes that variable-speed control of a ring frame on woolen or worsted yarns would give the same results. Particulars of a number of tests on frames which have been equipped with automatic control are given. (Paper by Charles L. Irwin.)

WOODWORKING INDUSTRIES

Glue Joints. This paper covers the methods used in the commercial jointing of wood on a production basis. The modern straight-line rip saw versus the continuous-feed glue jointer is discussed and a practical method of hooking up the two machines in tandem for increased efficiency is described. The paper details the kinds of glues and their application, and traces the history of the jointing of wood through the ages to the latest type of machine. (Paper by G. M. Diehl.)

Furniture Distribution. No attempt is made by the author to discuss the subject of furniture distribution in all of its extensive ramifications. He particularizes as to only a few phases of the subject. Much of the discussion pertains to furniture markets, designing programs, and the relation of sales volume to production control. The retailing of furniture is considered only as it relates directly to the problem of the maker. (Paper by D. D. Fennell.)

Timber Research and the Wood Industries. This paper covers the results of research in general and details the benefits that have accrued in all lines of manufacture. The especial need for research in the woodworking industries is emphasized, and the question is raised whether that industry is apathetic to the advantages of research, notwithstanding that millions of dollars are being spent by institutions directly connected with wood products. On the chemical side, timber research has made wood the principal paper-making material as well as the chief source of rayon. Plans are suggested for the training of a class of workers that can develop the uses of wood. (Paper by W. Kynoch.)

Manufacture of Custom-Built Plywood. Increased use of paneling has been effected in recent years, particularly because commercial institutions have gone to great expense to beautify their stores and places of business. Paneling of this character is used chiefly for its eye value. Beautiful effects are obtained by matching veneers which are obtainable in a wide range of domestic and foreign goods. The manufacture of panels for these high-grade installations requires great care, and the steps in their production are detailed by the authors. (Paper by E. R. Morrison and E. J. Maroney.)

Why Research in Furniture Manufacturing? Instead of the more scientific and exact methods that are so commonly assumed to be research, the furniture business as treated by the authors seems to be in position to profit better by the application of the fundamental motives and actions of ordinary observation, interest, and curiosity. Much of the available research material from organized laboratories is not applicable to actual production methods. Many of the facts evolved by the work of research organizations cannot be put into instant practise in the operating methods of a furniture plant without further research being done upon them. The authors give in detail many of the problems which are to be found in the manufacturing end of the furniture industry. (Paper by G. R. Petrie and A. C. Saunders.)

BOOK REVIEWS AND LIBRARY NOTES

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E., and the A.I.E.E. It is administered by the United Engineering Trustees, Inc., as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets, and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Industrial Engineering and Management

INDUSTRIAL ENGINEERING AND MANAGEMENT. By Ralph M. Barnes. McGraw-Hill Book Company, Inc., New York, 1931. Cloth, 5¾ × 9, 366 pp., $3.50.

REVIEWED BY W. J. DONALD[1]

WHILE it can scarcely be said that this book covers all of the problems of industrial engineering and management, nevertheless it does cover, quite satisfactorily, two main problems, namely, industrial plant designing and equipment, and time and motion study, wages, and manufacturing costs. Appendixes cover such problems as the determination of economic lot sizes, depreciation data, and the design of printed forms. The book is obviously intended to be used as a textbook on these problems of factory management.

The plan of the book is to state the principles governing the particular subject discussed and to illustrate them by concrete cases from successful manufacturing concerns. In fact, the cases are presented rather fully and completely. This is one reason why, in this book, a number of other problems of factory management are omitted from consideration. Much of the material which appears in the book had been used previously in mimeographed form in the classrooms of two universities.

The volume is profusely illustrated in every section.

In spite of the fact that the book is intended chiefly for classroom purposes, nevertheless the profusion of statistical and factual data, as well as forms and charts, makes the volume also a valuable reference work for factory executives.

Social Integration

SOCIAL INTEGRATION (TECHNOSYNTHESIS). By Victor A. Endersby. Mimeographed Edition, 1933. Paper, with linen backstrip, 8¾ × 10¾ in., 163 pages, $2.50.

REVIEWED BY L. P. ALFORD[2]

THE EXPLANATORY title of this limited edition on the present economic situation is "The Alternative to Periodic Economic Disintegration." The volume is written in the engineering method and leads up to a suggestion which the author believes might rectify the economic mistakes of the past "....because capital, technology, and management are still in a relatively favorable position."

Taken as a whole the author gives one of the most carefully selected and convincingly presented arrays of statistical facts dealing with the phenomenon of depression that has recently appeared. The analytical work is particularly well done. The discussion of unemployment and the manufacturing situation deserve to be singled out for commendation.

The author attacks "technocracy" and "technolatry" with bare knuckles, characterizing them as "idle visions" and listing the fatal defects of Scott's attitude as:

(1) Open contempt for every social technique except that of a sort of pesudo-engineering, fatal to any just social direction.
(2) Complete ignoring and ignorance of the human factor, based upon a thoroughgoing materialism.
(3) Adherence to theory without sufficient analysis.
(4) Use of facts and figures to enforce theories rather than for the construction of theories.
(5) Reasoning and calculation from partial facts, where the whole is available.

After presenting the need for regulative bodies in our complex civilization, and pointing out the difficulty of developing leadership, the author offers his own plan "idealistically set forth."

"There should ultimately be a national body—call it a Board of Technosynthesis or of Social Integration—acting in an advisory capacity to similar bodies in all parts of the country." This body "in turn would be principally instrumental in forming or stimulating boards everywhere. They should comprise representatives of all branches of science, all branches of business and finance, labor, and all branches of engineers, with a good sprinkling of lawyers." The tasks to be undertaken by these boards would comprehend (1) education, (2) overhead control of technology, (3) control of unemployment, (4) debt adjustment, (5) railroads, (6) farms, (7) engineering, and (8) tax problems.

After presenting his plan and explaining it in detail, Endersby, in a spirit of complete candor, proceeds to pull down the structure he has built by appraising the present tendencies and practical possibilities.

"We may sum up the situation with regard to forcible control as follows: (*a*) It requires a constitutional amendment. This is not to be expected short of a revolution. (*b*) Such a dictation, because of the magnitude and complexity of the problem, would, except for arbitration, be largely the tool of the numerous bodies necessary."

The final chapter is an outline of a Course in Technosynthesis, "the new form of economic education."

Amid the many presentations of plans to cure our economic and social ills, this book is worth reading because of three

[1] James O. McKinsey & Co., New York. Assoc. A.S.M.E.
[2] Vice-President, The Ronald Press Company, New York, N. Y. Mem. A.S.M.E.

features: (1) the excellent organization of factual information, (2) the balanced judgment as to what will work in our American life, (3) the emphasis on education.

Industrial Management in This Machine Age

INDUSTRIAL MANAGEMENT IN THIS MACHINE AGE. By Francis A. Westbrook. Thomas Y. Crowell Company, New York, 1932. Cloth, 6 × 9 in., 407 pp., charts, tables, $3.50.

REVIEWED BY W. J. DONALD[3]

ESSENTIALLY, this volume is the work of a journalist. There is nothing particularly original in the book, whole chapters being, in some cases, summaries of volumes previously published by others. It does reflect very wide reading and very liberal use of material published elsewhere. One particular chapter describes how telephone companies forecast future population trends—material not readily available.

There are three main criticisms of this volume:

(1) There is no logical sequence to the chapters. For example, the chapters on research applied to sales and the organization of the sales departments are followed by a chapter on the organization and functioning of the engineering department. Later on, there is a chapter on warehousing and distribution.

(2) A chapter on the organization of the purchasing department deals only incidentally with organization and largely with the actual procedures of a purchasing department.

(3) The author's theory of organization is decidedly weak. Illustrations may be found, for example, in the treatment of the organization and functions of a personnel department, in which it is apparent that the author believes that the personnel department performs the whole personnel job, and in which he discloses that he has little conception of the personnel job as a function of an operating executive facilitated by a personnel department. Similarly, in the treatment of office management, the author assumes that in most cases the office manager has jurisdiction over all the clerical work, whether in the selling, accounting, financial, or manufacturing departments.

Books Received in the Library

AIRCRAFT AND THE LAW. By H. L. Brown. Robert O. Ballou, New York, 1933. Cloth, 6 × 9 in., 359 pp., $3. The reader without legal training will find here an account of the law relating to aircraft, in everyday language. The rights, liabilities, and duties of those who operate and use aircraft, as they have been determined by regulations and litigation, are covered at length.

ARCHITECTURAL PLANNING OF THE AMERICAN COLLEGE. By J. F. Larson and A. M. Palmer. McGraw-Hill Book Co., New York and London, 1933. Cloth, 8 × 10 in., 181 pp., illus., diagrams, $2. This volume, the outgrowth of an architectural advisory service maintained by the Association of American Colleges, describes and illustrates recent developments in college architecture with special reference to the liberal arts college. The work is intended especially for college presidents and trustees responsible for the physical development of the institution.

DIE BESTIMMUNG DER DÄMPFUNG VON DREHSCHWINGUNGEN EINER FLUGMOTORKURBELWELLE. Dissertation by J. L. Mansa, of the Karlsruhe Technische Hochschule, Germany; printed in Kopenhagen, Levin & Munksgaard, 1933. Paper, 6 × 8 in., 76 pp., 5 kr. This dissertation describes and discusses critically a method used by the author to determine the damping of the torsional vibration in an airplane engine. The experimental work and the methods of calculation are described in detail.

[3] James O. McKinsey & Co., New York. Assoc. A.S.M.E.

COST ACCOUNTING, Principles and Methods. By C. Reitell. International Textbook Co., Scranton, Pa., 1933. Cloth, 6 × 10 in., 441 pp., charts, tables, $3.50. In this new text upon cost accounting there is, in addition to established principles and procedures, consideration of certain phases of costing which have had little consideration, according to the author, in previous books. These include the use of cost accounting to measure and evaluate plant performance, the treatment of overhead expense as an item to be controlled rigidly and kept in definite relation to production, and the stressing of managerial foremanship. Other features are the inclusion of standard costs and budgets as an integral part of the text, the consideration of distribution costs, and a chapter on the presentation of cost data for executives.

DAMPFSPEICHERANLAGEN. By W. Goldstern. J. Springer, Berlin, 1933. Leather, 6 × 10 in., 150 pp., illus., diagrams, charts, tables, 18 rm. The aim of this book is to provide a complete, systematic discussion of the whole subject. The principles, design, and construction of the prevailing types of accumulators are considered, the various uses described, and the economics of the subject discussed.

DIE ELEKTRISCHE WARMBEHANDLUNG IN DER INDUSTRIE. By E. F. Russ. R. Oldenbourg, Munich and Berlin, 1933. Cloth, 7 × 10 in., 259 pp., illus., diagrams, charts, tables, 14 rm. To his earlier books on electric metal furnaces and steel furnaces, the author now adds a volume upon heating furnaces and their applications for heating, drying, enameling, tempering, annealing, etc. The fields to which electric heating is adapted are first described, after which the general construction of the electric furnace is treated. The remainder of the book describes a large variety of furnaces for special purposes. The treatment is practical throughout and affords a good survey of present developments.

ELEMENTARY STEAM POWER ENGINEERING. By E. MacNaughton. Second edition. John Wiley & Sons, New York, 1933. Cloth, 6 × 9 in., 649 pp., illus., diagrams, charts, tables, $5. The aim of this work is to discuss clearly and concisely the fundamental principles underlying the construction and operation of the equipment of the steam power plant. The discussion uses but a minimum of mathematics, and practical phases of each topic are described before the theory is considered. The new edition has been thoroughly revised and new material added to bring it up to date.

ELEMENTS OF POWER GENERATION. By A. M. Greene, Jr. John Wiley & Sons, New York, 1933. Cloth, 6 × 9 in., 314 pp., illus., diagrams, charts, tables, $3.25. Intended to give the young engineering student and the general reader an appreciation of the various ways in which power is obtained from natural sources, this book describes the principles, limitations, and operation of the equipment of the modern power station. The treatment is descriptive and designed to enlarge the vocabulary of the reader. Little theoretical matter is included. The book is a successor to Spangler, Greene, and Marshall's "Elements of Steam Engineering."

FAN ENGINEERING. Edited by R. D. Madison and W. H. Carrier. Third edition. Buffalo Forge Co., Buffalo, 1933. Leather, 4 × 7 in., 622 pp., illus., diagrams, charts, tables, $3. A convenient collection of numerical and technical data frequently wanted by users of fans. Part one discusses the general physics of air and the matter of air flow. Part two deals with the uses of fans for air conditioning, heating, drying, combustion, dust removal, and other industrial purposes. The final section discusses the selection of fans and gives performance tables, dimensions, and other information concerning the products of the publisher. The work brings much useful information together in convenient form.

GENERAL PROPERTIES OF MATTER. By F. H. Newman and V. H. L. Searle. Second edition. Macmillan Co., New York, 1933. Cloth, 6 × 9 in., 388 pp., diagrams, tables, $4. The aim of this book is to present a fairly complete survey of the fundamental properties of matter, especially developing those branches of the subject, such as surface tension, osmosis, and viscosity which verge toward chemistry, and hydrodynamics and vibrations, which are more particularly of importance to the mathematician and engineer. The authors explain the necessary mathematics but assume a knowledge of the calculus.

HUMAN NATURE AND MANAGEMENT. By O. Tead. Second edition. McGraw-Hill Book Co., New York and London, 1933. Cloth, 6 × 8 in., 338 pp., $3.50. This book discusses the fundamentals of psychology in a concise, yet comprehensive manner, and explains how they may be applied to management. Numerous illustrations of the application of psychological knowledge to specific tasks are included. The work is intended for executives interested in man management.

INDEX TO THE LITERATURE OF FOOD INVESTIGATION, Vol. 4, No. 2, Sept., 1932. Department of Scientific and Industrial Research, London, 1933. Paper, 6 × 10 in., 182 pp., 2s 6d. (British Library of Information, New York.) This index covers thoroughly the recent literature upon the preservation and transport of food, including much of interest to engineers upon canning, temperature, and humidity control, transport by sea, rail, and road, heat insulation, refrigerating machinery, and air conditioning. Over ninety periodicals are indexed and the entries are annotated.

INTERNATIONAL ACETYLENE ASSOCIATION, OFFICIAL PROCEEDINGS. 32nd Annual Convention, Congress Hotel, Chicago, November 11, 12, 13, 1931. International Acetylene Association, New York, 1932. Cloth, 6 × 9 in., 259 pp. Various aspects of the acetylene industry are discussed in this volume of proceedings. Especial attention was given to acetylene welding and its use in rail bonding, pipe welding, and the chemical industry. Methods of educating welders, of testing welds, and other topics were also discussed.

INTERNATIONAL CRITICAL TABLES OF NUMERICAL DATA, PHYSICS, CHEMISTRY AND TECHNOLOGY. INDEX, Volumes 1–7. Edited by National Research Council. McGraw-Hill Book Co., New York and London, 1933. Cloth, 9 × 11 in., 321 pp., $6. A difficulty inherent in the plan of the Tables has been that of ascertaining what data they contain about a specific material. This is overcome by the index. Here are listed alphabetically the chemical compounds and systems, industrially important materials, minerals and rocks, the names of effects and formulas, and such general properties of materials as boiling points, refractive indexes, etc., with references to the proper table. Owners of the Tables will find the new volume indispensable.

INTRODUCTION TO RAILWAY MECHANICS. By G. V. Lomonossoff. Oxford University Press, London, 1933. Cloth, 6 × 9 in., 179 pp., diagrams, charts, $3.75. In this concise presentation of the basic laws of railway mechanics, Dr. Lomonossoff presents the substance of his lectures at the California Institute of Technology. The book is addressed to engineers who wish to become acquainted with the scientific methods of solving railway problems, and scientists who wish to find railway problems in the solution of which they can participate. The volume is to be followed by others in which various aspects of railway mechanics will be discussed systematically.

JAHRBUCH DER BRENNKRAFTTECHNISCHEN GESELLSCHAFT E. V., Vol. 13, 1932. Wilhelm Knapp, Halle (Saale), 1933. Paper, 8 × 11 in., 66 pp., illus., diagrams, charts, tables, 7.20 rm. The four papers here presented discuss problems connected with the use of the internal-combustion engine for transport. Dr. Thau considers the problem of obtaining suitable fuels from coal, and describes recent advances in that direction. Dr. Frank discusses methods of obtaining motor fuel from lignite and peat. Mr. Ostwald reports the results of experiments with suction gas producers. Dr. Charpentier considers the use of petroleum derivatives for motors.

KÄLTEPROZESSE. By P. Ostertag. Second edition. J. Springer, Berlin, 1933. Cloth, 6 × 10 in., 112 pp., diagrams, charts, tables, 8.80 rm. By using the entropy diagram to explain the various processes of refrigeration, the author is able to solve the problems of the designer of refrigerating plants with clearness and simplicity. The method is illustrated by numerous examples in this work.

Special attention is given to multi-stage compressors and turbo-compressors. The book also contains entropy diagrams for ammonia, carbon dioxide, sulphur dioxide, and ethyl bromide, as well as Mollier diagrams for first two of these.

NEUERE WEGE IN DER METALLURGIE DER LAGER- UND WEISSMETALLE. By F. Vogel. Wilhelm Knapp, Halle (Saale), 1933. Paper, 6 × 9 in., 97 pp., diagrams, charts, tables, 7.50 rm. Methods for converting scrapbearing metal and type metal, tin ash, lead residues, and other non-ferrous waste metals into marketable alloys are discussed theoretically and practically in this work. The advantages and defects of various methods of wet and dry refining are discussed. The book is intended to assist the smelter of scrap metal to plan a procedure that will be economical and efficient.

LA NITRURAZIONE DELL' ACCIAIO. By Federico Giolitti. Ulrico Hoepli, Milan, 1933. Paper, 7 × 10 in., 452 pp., illus., diagrams, charts, tables, 60 lira. In preparing this, the first comprehensive book on nitriding, Dr. Giolitti has drawn upon his own experience for many of the data, but has also reviewed most of the important papers on nitriding published before 1932.

The book is in three parts. Part one reviews early and recent investigations of the effect of nitrogen in steel. Part II is on the nitriding process. One lengthy chapter is devoted to the steels, including melting and processing, classes of steel, and the effect of various alloying elements on the steels used for nitriding. Another, on treatment prior to nitriding, summarizes the effect of thermal and other treatments on the steel. The third chapter, on the nitriding operation, includes a discussion of furnaces, proper technique, and costs.

The third section of the book is entitled "Technical Applications." The chapter on properties is a comprehensive discussion of hardness and mechanical properties, wear and abrasion resistance, and the effect of elevated temperatures. Methods of determining the properties are given detailed attention. The last chapter is devoted to the commercial use of nitrided steel, particularly in the automotive, aircraft, and machine-tool industries.

PERSONNEL ADMINISTRATION. By O. Tead and H. C. Metcalf. Third edition. McGraw-Hill Book Co., New York and London, 1933. Cloth, 6 × 9 in., 519 pp., charts, $4. The administration of human relations in industry is discussed in a practical manner in this manual, which is intended for heads of personnel departments and executives concerned with the selection, training, and control of employees. In this edition special attention is given to new aspects and problems of personnel administration which recent economic developments have made prominent.

PETROLEUM CODE HANDBOOK 1933, a Standard Handbook, Register and Buyer's Guide. Edited and published by Leonard M. Fanning, New York. Paper, 9 × 11 in., tables, $5. The Code brings together much information of interest to marketers of petroleum products, including a directory of independent jobbers and service stations, a buyer's guide, and data upon refineries, motor vehicle and gasoline taxes, fire prevention, service-station operation, etc. This edition also contains basic statistical tables of the petroleum industry, compiled by the American Petroleum Institute and corrected to the end of 1932.

POPULATION TRENDS IN THE UNITED STATES. By W. S. Thompson and P. K. Whelpton. McGraw-Hill Book Co., New York and London, 1933. Cloth, 6 × 10 in., 415 pp., diagrams, charts, tables, $4. In gathering the information on population for the President's Research Committee on Social Trends extensive compilations were accumulated which could not be included in the Committee report. These longer tables are presented here and their significance discussed in greater detail. The book attempts to give a more complete picture than has been available hitherto and to project past trends into the future.

PUBLIC UTILITY RATE STRUCTURES. By L. R. Nash. McGraw-Hill Book Co., New York and London, 1933. Cloth, 6 × 9 in., 379 pp., charts, tables, $4. The object of this work is to present a compilation of technical, as distinct from legal, information about rate practices and applications. Such topics as rate reduction, promotional rates, regulation of rates versus regulation of profits, cost analyses, and economic factors are discussed, and references provided for further reading. In addition to this general discussion of principles and methods, the distinctive features of the rate structures used by electric, gas, local transportation, communication, water, and street-lighting services are considered.

RIPPER'S STEAM ENGINE THEORY AND PRACTISE. By W. J. Goudie. Eighth edition. Longmans, Green & Co., London and New York, 1932. Cloth, 6 × 9 in., 841 pp., illus., diagrams, charts, tables, $7. The developments of the nineteen years since the last edition of this work have been so marked that Professor Goudie has entirely rewritten this textbook, in order to bring it into line with present theory and practise. The new work, much larger than its predecessor, is a comprehensive college text covering the fundamentals of steam-engine design and management. Worked-out examples are included.

SPEED AND POWER OF SHIPS. Revised edition. By D. W. Taylor. Ransdell, Inc., Washington, D. C., 1933. Cloth, 9 × 12 in., 366 pp., illus., diagrams, charts, tables, $2.50. The United States Shipping Board, by presenting this new edition of Rear Admiral Taylor's well-known treatise, has done a service to students of naval architecture. The work aims to give a consistent, connected account of the theory of resistance and propulsion of vessels, accompanied by methods, rules, and formulas that may be applied in practise. The book has been revised in the light of developments since 1910 but remains, in general, as before.

STANDARD COSTS. By H. E. Kearsey. Sir Isaac Pitman & Sons, Ltd., London, 1933. Cloth, 6 × 9 in., 177 pp., charts, tables, $2.25. The

subject of costing is discussed in a broad way, without reference to specific industries. The purpose is to explain and illustrate modern tendencies, to emphasize the need for scientific method, and to point out advantages to executives who are not conversant with standard costing.

TECHNICAL MAN SELLS HIS SERVICES. By E. Hurst. McGraw-Hill Book Co., New York and London, 1933. Cloth, 6 × 8 in., 239 pp., $2. The purpose of this book is to help the technical man find a job. The author writes from extensive experience in helping college graduates to find positions, which experience he here condenses into a series of typical cases that illustrate the methods advocated.

ÜBER DEN SCHUBAUSGLEICH UND DIE BERECHNUNG DES ACHSIALSCHUBES BEI DAMPFTURBINEN. Dissertation by M. J. Gercke. Technische Hochschule, Hannover, 1931. Paper, 6 × 8 in., 94 pp., charts, tables. This dissertation is devoted to an examination of the axial thrust in the steam turbine and to methods of balancing it. In the first section the author gives a historical review of the evolution of thrust bearings, based upon German and English patents. The second section is concerned with the systematic investigation of the static thrust and the development of methods for its calculation. Equations are derived which are widely applicable.

DIE WÄRMEAUSTAUSCHAPPARATE. (Sammlung Göschen 1067.) By E. Kirschbaum. Walter de Gruyter & Co., Berlin and Leipzig, 1933. Cloth, 4 × 7 in., 104 pp., illus., diagrams, charts, 1.62 rm. The principles underlying the design of heat exchangers, evaporators, and condensers, together with the basic equations, are presented and their use illustrated in this little book.

WHAT'S GOING ON

Metal Congress to Meet in Detroit

THE 1933 Metal Congress will meet in Detroit, October 2 to 6, and at the Convention Hall simultaneously with the National Metal Exposition under the auspices of the American Society of Steel Treating. Participation in the Congress by The American Society of Mechanical Engineers will be through its Detroit Section which will sponsor a morning session on machine-shop practise. A. N. Goddard will act as chairman of the session and the speakers will be C. L. Eksergian, chief engineer, Budd Wheel Co., Detroit, on "Characteristics and Methods of Tests of Automotive Brake Drums," and Gordon M. Evans, vice-president in charge of manufacturing, Kelvinator Corporation, Detroit, on "Simplicity, the Solution of Extreme Accuracy in Quantity Production."

Other societies participating in the Congress are the Institute of Metals and the Iron and Steel Division of the American Institute of Mining and Metallurgical Engineers, the American Welding Society, the Wire Association, and the American Society of Steel Treating.

A.P.I.-A.S.M.E. Unfired Pressure-Vessel Code

THE WORK of the Joint A.P.I.-A.S.M.E. Committee on Unfired Pressure Vessels has progressed to the point where it seems desirable to distribute copies of the following five sections of the proposed code for the constructive comment of those interested:

Section A—Highest-Grade Fusion-Welded Vessels
Section B—Second-Grade Fusion-Welded Vessels
Section C—Highest-Grade Riveted Vessels
Section D—Second-Grade Riveted Vessels
Section F—Rules for Periodic Inspection and Allowable Working Pressure for Existing Vessels

These drafts are tentative only, and have not received the final approval of the Joint Committee.

Copies of the code may be secured by communicating with Dr. R. P. Anderson, secretary, 250 Park Ave., New York, N. Y., care of the American Petroleum Institute. The committee plans to hold its next meeting in September.

It will be recalled that the Joint Committee on Unfired Pressure Vessels was organized in the fall of 1931 and held its first meeting on December 1, 1931, at which Walter Samans was elected chairman and Dr. R. P. Anderson, secretary. Six meetings have been held, five in New York and one in Tulsa, Okla.

The committee consists of ten members, five being named by each sponsor society. The A.P.I. representatives are Walter Samans, A. J. Ely, K. V. King, R. E. Ost, and R. C. Powell, and the A.S.M.E. representatives are D. S. Jacobus, E. R. Fish, E. H. Brown, R. E. Cecil, and J. Partington.

Candidates for Membership in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after September 25, 1933, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Members desiring further information, or having comments and objections, should write to the Secretary of the A.S.M.E. at once.

NEW APPLICATIONS

BABAYCON, M. A., Ahmedebad, India
BLACK, W. G., Cleveland, Ohio
BLISS, HENRY W., Indianapolis, Ind.
BROOKS, G. IRVING, Spokane, Wash.
BURGOYNE, CHAS. LYMAN, Norwood, Ohio
CRAIN, HAROLD F., Ottawa, Canada
FABIROSKI, JOSEPH P., Brooklyn, N. Y.
FAHY, JAMES A., New York, N. Y.
GRUNWALD, LOUIS J., Milwaukee, Wis.
HALL, J. M., Chicago, Ill.
HESS, WILLIAM B., Dallastown, Pa.
HOPPER, E. J. B., Lufkin, Texas
JOHNSEN, GEORGE JOHN, Jersey City, N. J.
KING, HENRY F., Cambridge, Mass.
LANCASTER, KENNETH G., Junction City, Kans.
LOXTERMAN, HENRY R., Edgewood, Pa.
MARDEN, JACK, Seattle, Wash.
MAXWELL, MARSHALL R., Alva, Okla.
MAYS, FLOYD R., Chicago, Ill.
MILLER, ROY R., Port Ludlow, Wash.
MONROE, EDWIN T., Pikeville, Ky.
MULLER, OTTO, Southbridge, Mass.
NANAWA, JOSE NATIVIDAD, Chicago, Ill.
NUGEY, ANTHONY L., New York, N. Y. (Rt.)
PALMER, RALPH M., New York, N. Y.
PESCE, ANTHONY T., Brooklyn, N. Y.
PESCE, LUCIANO, Brooklyn, N. Y.
PETTEBONE, ORLANDO R., Oakland, Calif.
PLASSE, HERMAN, Brooklyn, N. Y.
REDMOND, JOHN H., Columbus, Ohio
REEVE, KENNETH A., Bound Brook, N. J.
SACHDEV, MOHAN LALL, Punjab, India
SCHAEFER, FREDERICK LEROY, Charleston, W. Va.
SCHMIDT, KNUTE, New York, N. Y.
SCHWARTZ, LOUIS, Bronx, N. Y.
SCHWEITZER, PAUL H., Prof. (Rt.)
STEEN-JOHNSEN HALL, New York, N. Y.
SUMMO, NICHOLAS C., New York, N. Y.
SUMMO, VINCENT P., New York, N. Y.
WERNER, FREDERICK W., Prospect Park, Pa.
WOODWORTH, WETHERED, San Francisco, Calif.

CHANGE OF GRADING

Transfers from Junior

DIDRIKSEN, HERLUFF, Bound Brook, N. J.
EVARTS, HOWARD M., Buffalo, N. Y.
FEYRER, WILLIAM F., Norwalk, Conn.
HALPERSON, ALEXANDER S., Brooklyn, N. Y.
KASSNER, PAUL A., Newark, N. J.
KUSOLD, CHARLES, Brooklyn, N. Y.
LAMPHIER, HIRAM I., Springfield, Ohio
LEGRIS, LEOPOLD A., Providence, R. I.
MCCABE, VALENTINE, Brooklyn, N. Y.
MARTIN, HENRY H., JR., New Bedford, Mass.
MCMAHON, JEROME B., Sharon, Mass.
RING, VINCENT P., St. Louis, Mo.
SORENSEN, READER W., Chicago, Ill.
SPEAR, ROBERT D., Los Angeles, Calif.
SOKOLOFF, NICHOLAS, New York, N. Y.
STEVENS, CARL A., Pontiac, Mich.
THUESEN, HOLGER G., Stillwater, Okla.
WASSINK, HARRY J., Grand Rapids, Mich.
YATES, JAMES L., Buffalo, N. Y.